Emerging distribution planning analyses

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GE Energy Consulting

Distribution Systems and Planning Training for Western States, May 2-3, 2018

Outline

- ► Introduction
- ► Multiple scenario forecasts
- ► Hosting capacity
- ► Locational net benefits analysis
- ► Key questions to ask

Introduction

Passive DER Planning

Autonomous DER deployment with little information/guidance

- ► Customer decides what kind of DER to install, how big, where, and how to operate it
  - Utilities must manage integration of the DER
  - Location may be unfavorable leading to expensive interconnection and no one is happy
- ► If the next DER requires upgrade/mitigation, that next customer is responsible, even though it might enable many more customers to install DERs
- ► Utility compensates customer (e.g., net metering, fixed tariff)
  - Compensation may not reflect actual net value that DER brings

Consequences of passive planning

- ► 6 GW of uncontrolled distributed PV (DPV), resulting in negative prices, overgeneration events, difficulty in forecasting load (California)
- ► Uncontrolled DPV that increases curtailment of wind plants (Maui)
- ► Projects in difficult locations that require challenging mitigation (National Grid)
- ► Inability to recover cost of service from DPV customers (multiple utilities)
- ► Unhappy customers who want to install DER but whose feeder can't accommodate additional DER (Hawaii)

Photos by NREL, 7400 and 14697

Smart, proactive planning

Give customers information about where the grid needs help. Incentivize them.

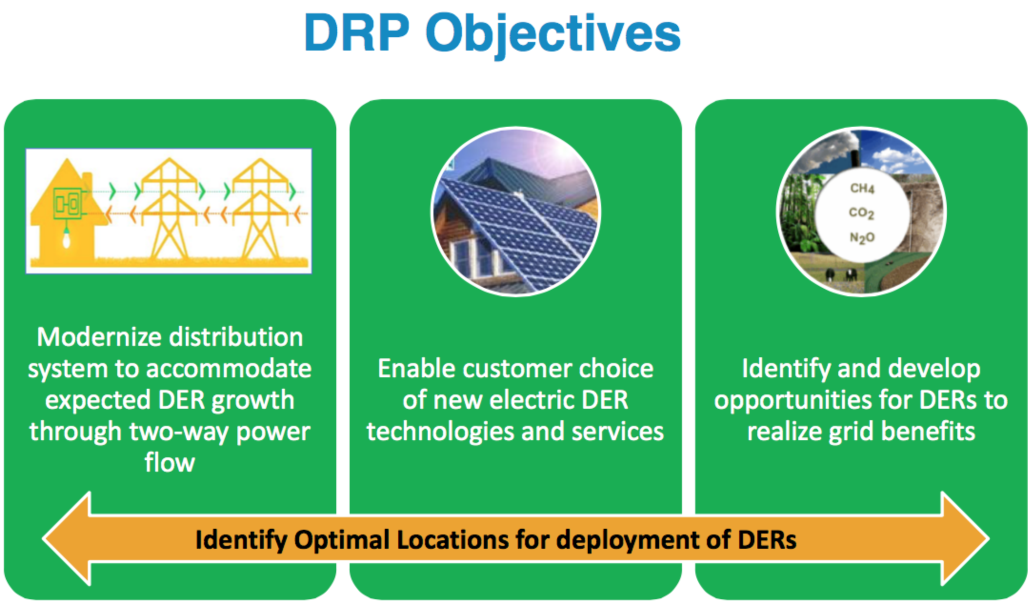
- ► Hosting capacity shows how much more DER can be managed on a given feeder easily, or where interconnection costs will be low/high
- ► Locational net benefits analysis helps determine the specific benefits of specific services at a specific location to guide developers
- ► Proactive upgrades of circuits that are likely to see DER growth
- ► Defer traditional infrastructure investments through non-wires alternatives that provide specific services at specific locations
- ► Help prioritize solicitations
- ► Inform rates and tariffs
- ► Leverage third-party capital investments

Distribution Resources Plans (DRPs)

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

- California’s 3 investor-owned utilities (IOUs) submitted DRPs to CPUC July 2015 http://www.cpuc.ca.gov/General.aspx?id=5071

- New York’s 6 IOUs submitted 5-year Distributed System Implementation Plans (DSIPs) as part of the Public Service Commission’s Reforming the Energy Vision (REV) initiative in June 2016. Supplemental DSIP in Nov 2016. http://jointutilitiesofny.org/



PG&E, DRP Webinar, 2015

Multiple Scenario Forecasts

Types of Scenarios

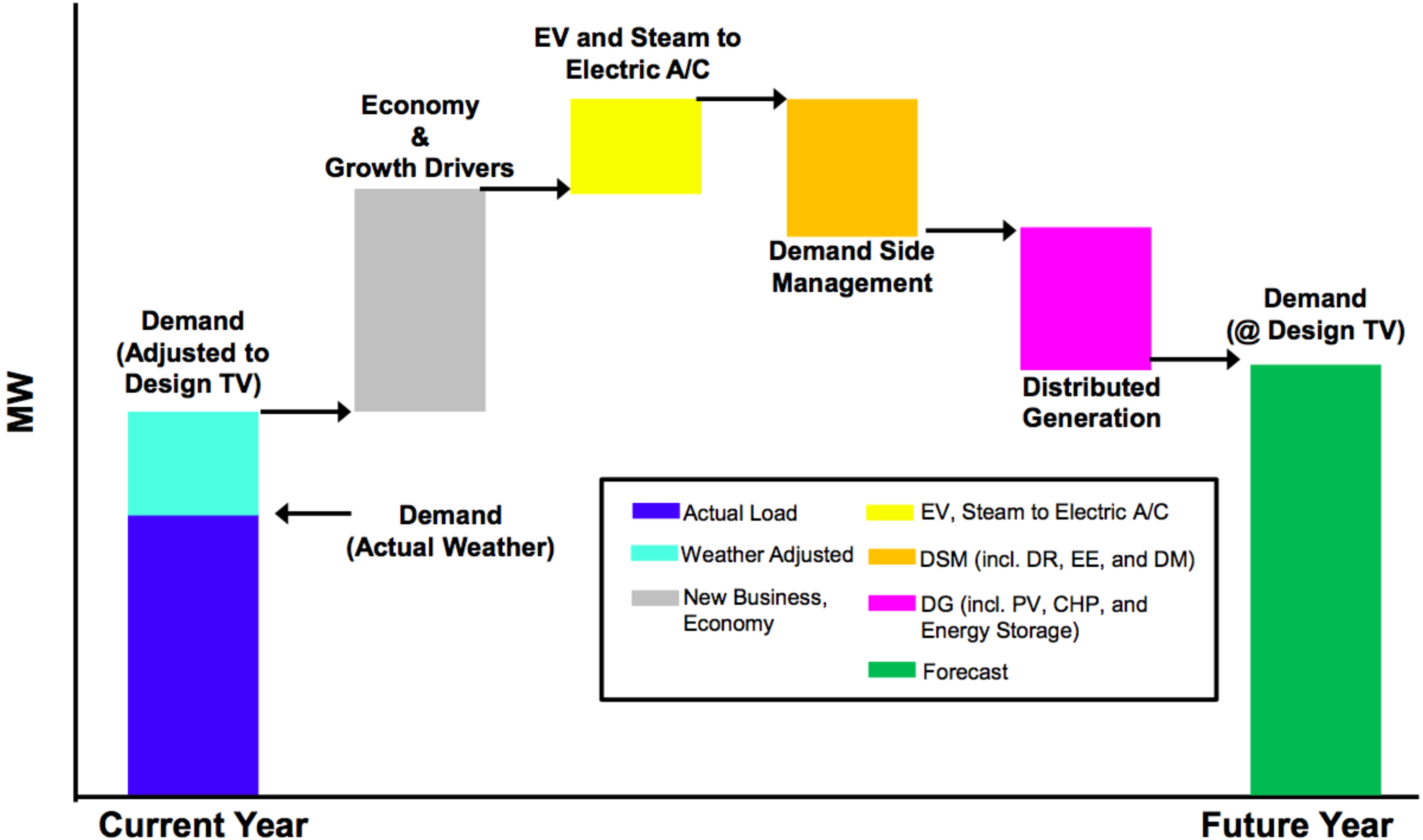
- Business-as-usual (eg, California's Trajectory case)
- High penetrations of DERs
- Costs decrease for certain DERs
- Policy-driven
- Carbon/sustainability
- High community choice aggregation scenario

What are the main drivers in your region?

Making load forecasts more granular in time and space

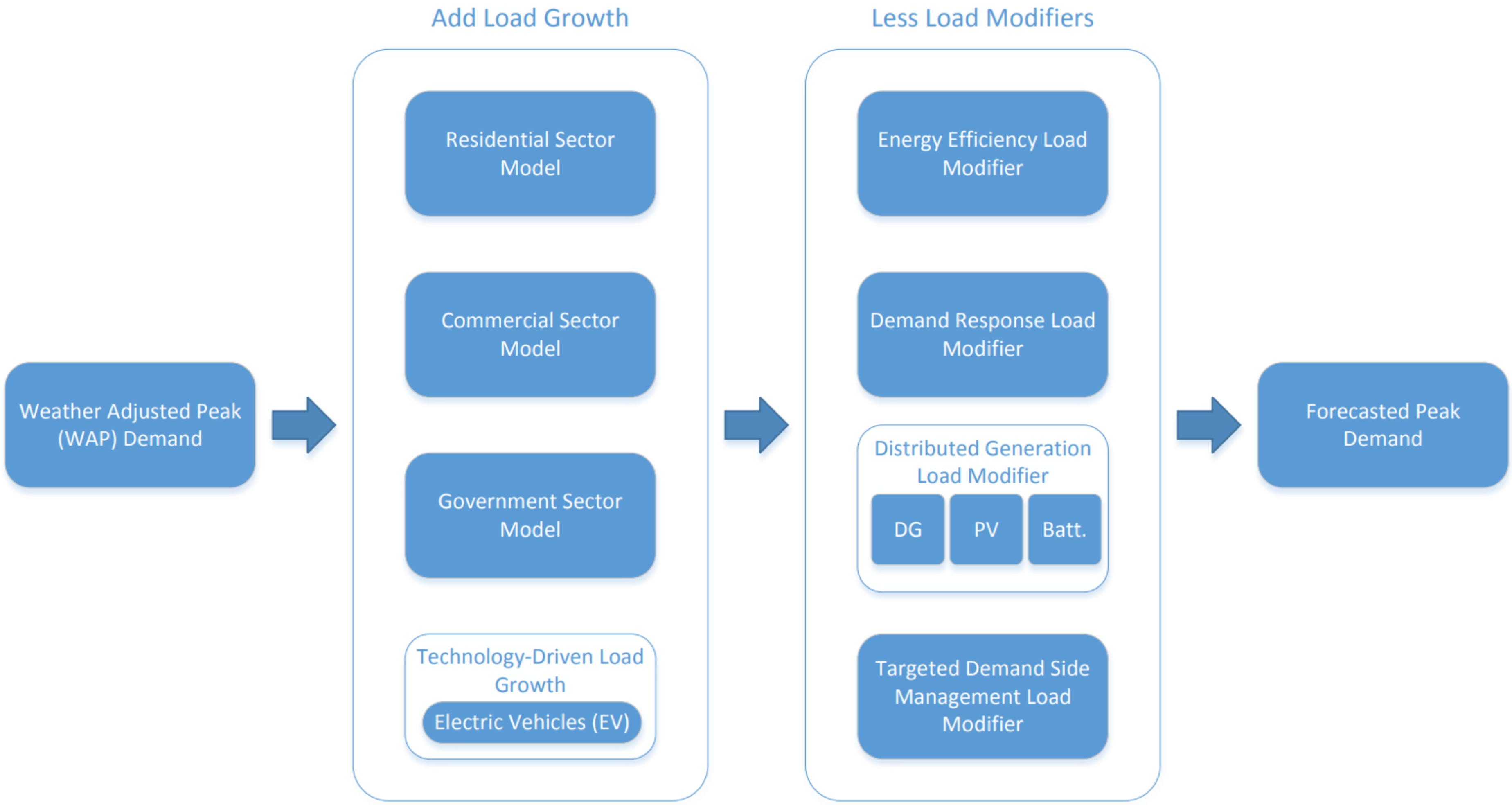
- State level: California
  - California Energy Commission Integrated Energy Policy Report
  - Annual peak load forecast
  - Annual energy
  - By climate zone
- Utility system level: Southern California Edison (SCE)
  - Annual hourly load forecast by customer class, accounting for DERs
- Utility distribution level: SCE
  - Annual peak hour by substation (subtransmission and below) with limited accounting for DERs at present
  - Goal: Annual hourly load forecast by feeder, accounting for all DERs

Example of Load Forecasting with DER



Con Edison, *Distributed System Implementation Plan*, June 30, 2016

Various models need to be run to determine each component

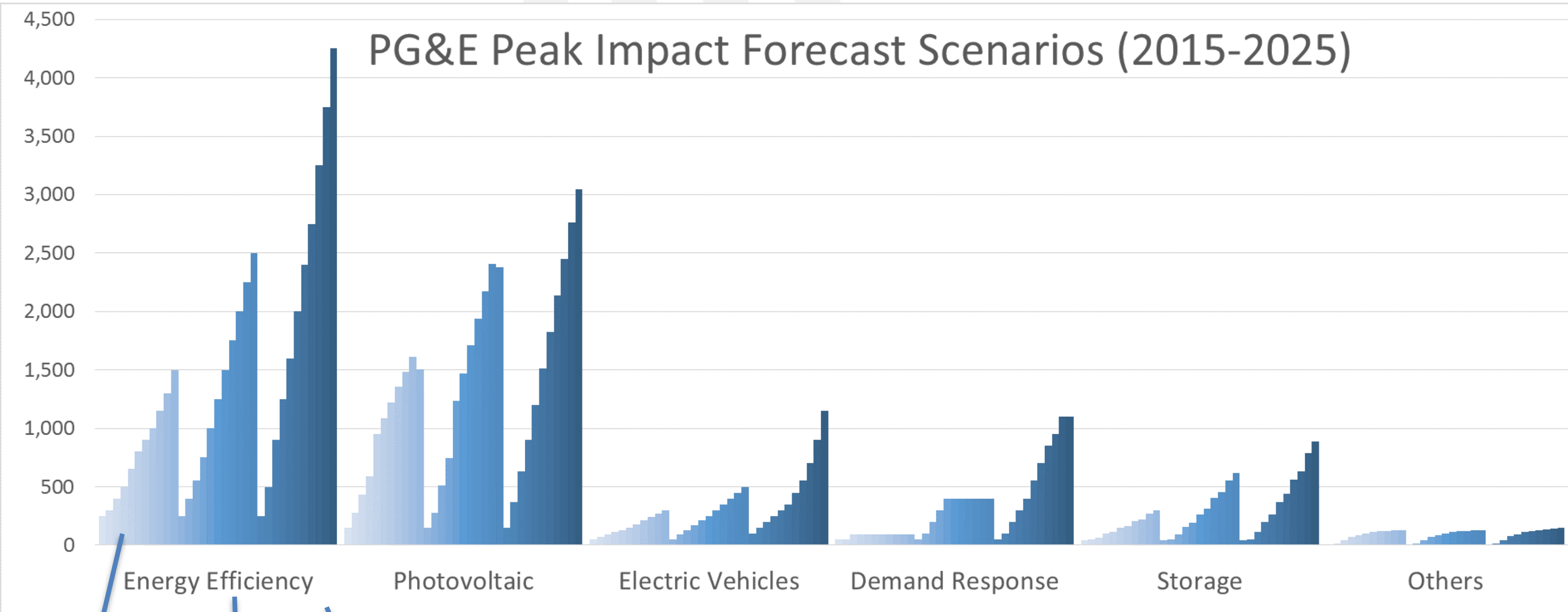


Con Edison, *Distributed System Implementation Plan*, June 30, 2016

Where does the data come from?

	SCE	PG&E	SDG&E
PV (BTM)	SCE Latest Forecast	Integrated Energy Policy Report (IEPR) Mid Case	SDG&E Latest Forecast
Energy Efficiency	IEPR – Low Mid AAEE and EE Potential & Goals Study	IEPR – Low Mid AAEE	IEPR– Low Mid AAEE
Load modifying Demand Response (DR)	DR Load Impact Report	IEPR Mid Case	DR Load Impact Report
Supply Resource DR	n/a	n/a	n/a
Electric Vehicles	SCE Latest Forecast	IEPR Mid Case	SDG&E Latest Forecast
Storage (BTM)	SCE Contracted Procurement	PG&E Contracted Procurement + Interconnection Queue	AB2514 Targets

Scenario Summary for PG&E



Hansell, Navigant Consulting, 2015

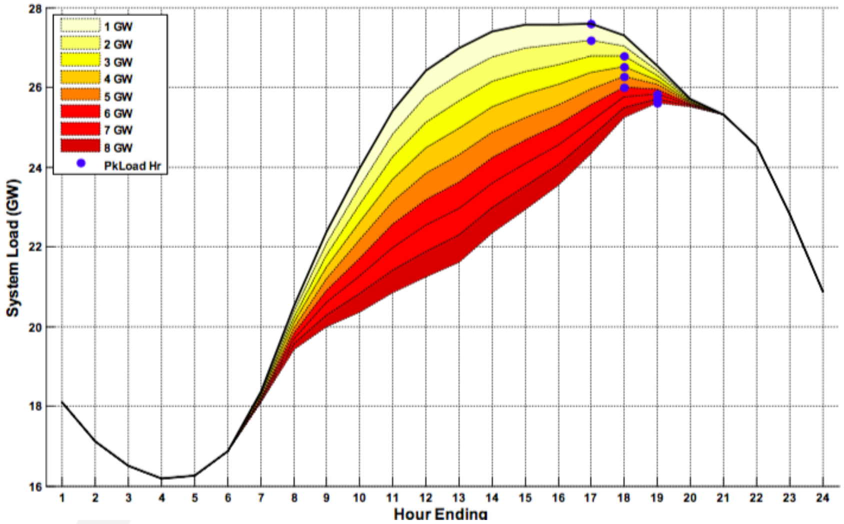
Trajectory

High Growth

Very High Growth

Load profiles/shapes are important

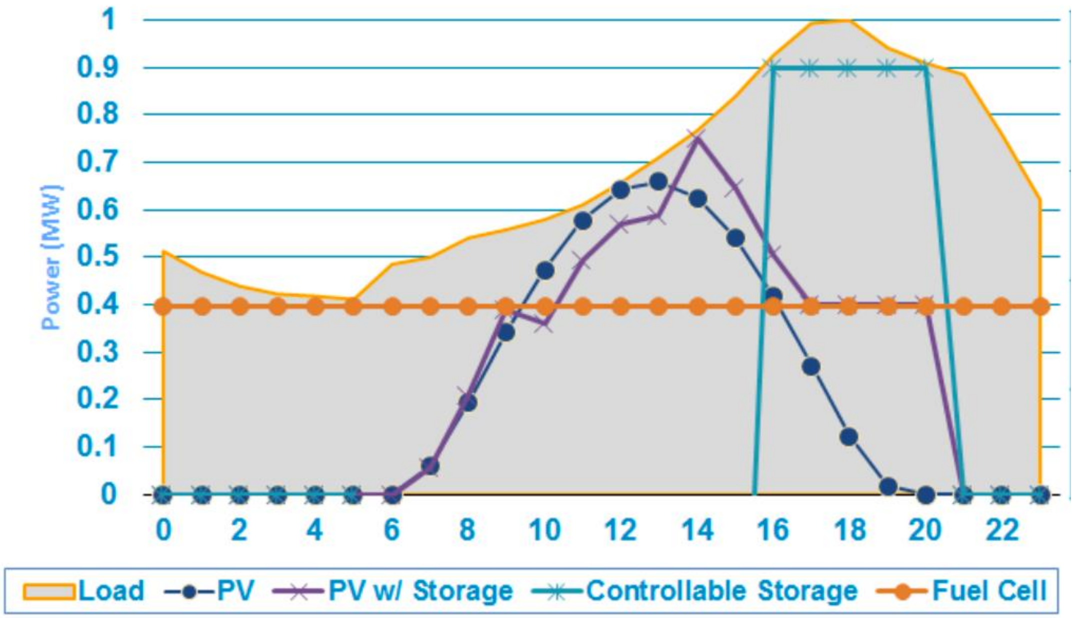
- ► Traditional generation offered fixed capability at all times
  - Resource adequacy could be determined by peak
- ► However, DERs may offer variable output
  - Resource adequacy needs to be based on hourly profile for peak day
- ► “Peak” is moving because of a changing grid
  - As we move to time-varying rates, as solar penetrations increase, as EVs proliferate, it becomes harder to predict when peak will be
- ► System peak is different from circuit peak



W. Henson, ISONE, 2016

Distributed Generation (DG)

- How much, where, when?
- How much does it contribute to peak demand?
- How much does it reduce energy demand?
- How is it operated?



Source: PG&E, DRP, 2015

Example: Constructing a Demand Forecast

2016 - Electric System Peak Demand Forecast (in Megawatts)

		2015	2016	2017	2018	2019	2020
1	**Updated System Forecast**	**13,600**	**13,781**	**13,942**	**14,048**	**14,124**	**14,164**
2	MW Growth:		181	161	106	76	40
3	% Growth:		1.30%	1.20%	0.80%	0.50%	0.30%
4	**Additional MW Growth (Incremental Rolling)**						
5	Electric Vehicles (EVs)		1	5	6	6	7
6	Steam A/C Conversion		11	22	33	43	54
7	**Load Modifiers (Incremental Rolling)**						
8	Photovoltaics/Solar (PVs)		-8	-29	-40	-51	-60
9	Distributed Generation (DG)		-22	-48	-85	-90	-91
10	Energy Storage		-2	-3	-3	-4	-4
11	**Coincident DSM (Incremental)**						
12	Con Edison EE		-22	-15	-19	-25	-25
13	NYSERDA EE		-5	-7	-8	-7	-7
14	NYPA		-7	-5	-5	-1	-1
15	BQDM		-6	-24	-6	13[27]	0
16	DMP		-36	-68	0	0	0
17	Demand Response		-32	-9	-8	-3	-3
18	Total Incremental DSM:		-109	-126	-46	-24	-36
19	Rolling Incremental DSM:		-109	-235	-281	-305	-341
20	**System Forecast less DSM, less DG, PVs and Batteries + EVs + Steam A/C**		**13,652**	**13,653**	**13,677**	**13,724**	**13,729**
21	MW Growth:		52	1	24	47	5
22	**Rounded System Forecast less DSM, less DR and PVs + EVs + Steam A/C**		**13,650**	**13,655**	**13,675**	**13,725**	**13,730**
23	MW Growth (Rounded):		50	5	20	50	5
24	% Growth:		*0.37%*	*0.04%*	*0.15%*	*0.37%*	*0.04%*

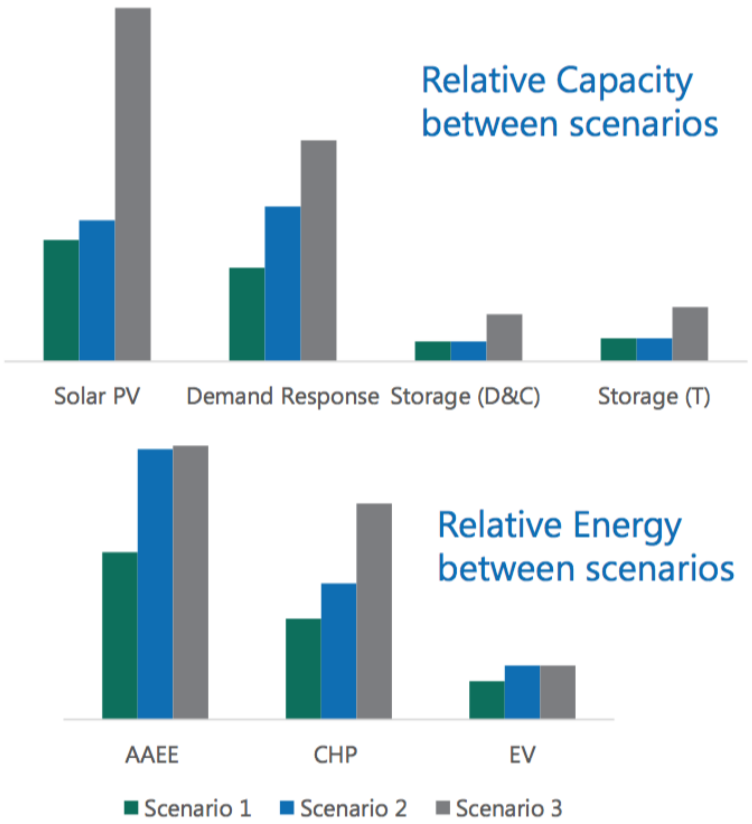
Con Edison, *Distributed System Implementation Plan*, June 30, 2016

DER Scenario Planning

SCE Territory Amounts of Potential DER Deployment by 2025

Growth Type	Scenario 1	Scenario 2	Scenario 3
Base Load	27,019 MW	27,019 MW	27,019 MW
Solar PV (nameplate AC)	1,636 MW	1,905 MW	4,770 MW
AAEE (annual)	10,536 GWh	17,031 GWh	17,243 GWh
Demand Response	1,265 MW	2,087 MW	2,981 MW
CHP (annual)	6,350 GWh	8,576 GWh	13,612 GWh
EV (annual)	2,422 GWh	3,395 GWh	3,395 GWh
Storage (D&C)	270 MW	270 MW	637 MW
Storage (T)	310 MW	310 MW	731 MW

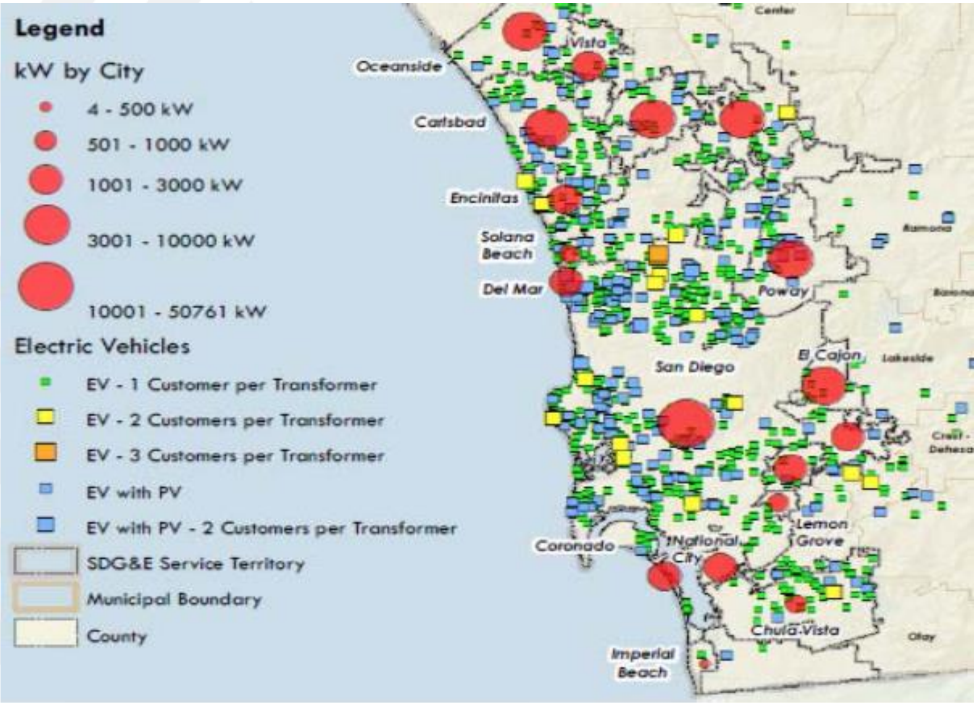
Southern California Edison, Distribution Resource Plan, 2015



Growth rate declines from 1.4% to 0.2 – 1.0%

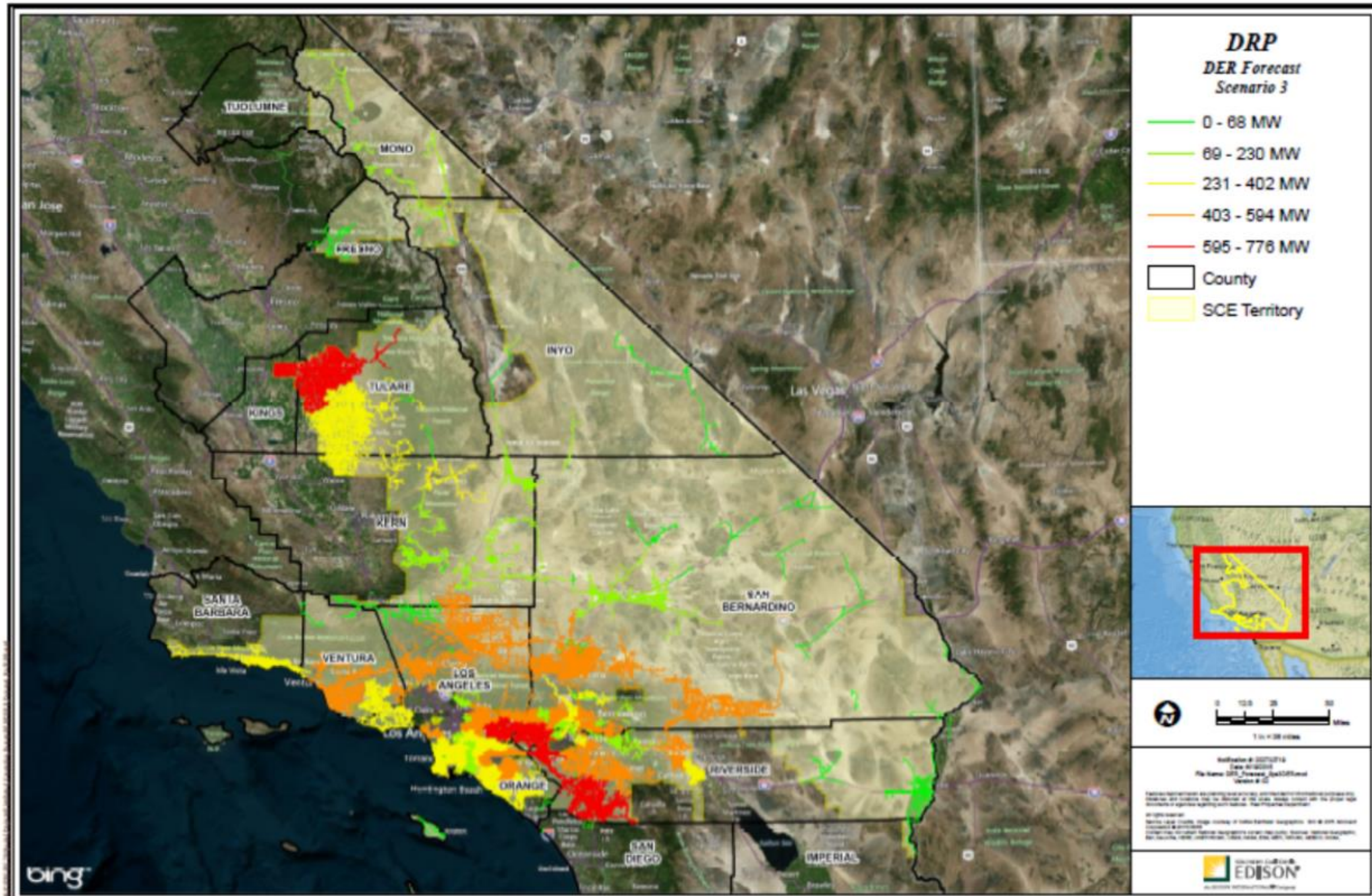
Allocate DERs to feeders

- ► ***Ignore limitations of existing distribution grid***
- ► Identify likely adopters:
  - Who is likely to have interest in different DERs?
  - Who is likely to have economic potential to install different DERs?
- ► What are some of the drivers?
  - ***Potential savings***
  - Clustering effect
  - Early adopter effect
  - Green customers
  - Self-sufficiency
  - Income levels
- ► What data can help?
  - Existing installations
  - Interconnection queue
  - Customer surveys/studies



Frank Goodman, SDG&E, UVIG Spring Workshop, 2016

Very High Growth DER Scenario - SCE



Southern California Edison, Distribution Resource Plan, 2015

Integration Capacity Analysis/ Hosting Capacity

Hosting Capacity

- Amount of DER that can be accommodated without adversely **impacting** power reliability or quality under **current** configurations, without requiring mitigation or infrastructure **upgrades**

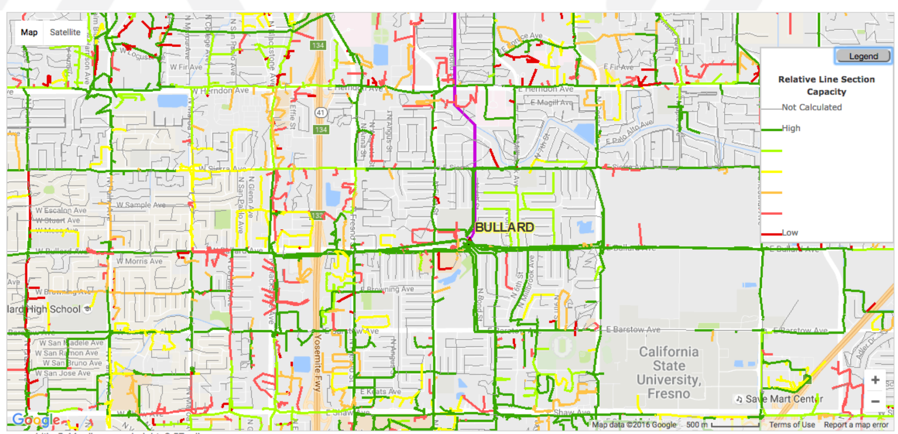
$$\max P_{DER}$$

0.6 MW

$$\frac{\max P_{DER}}{\max P_{LOAD}}$$

15 %

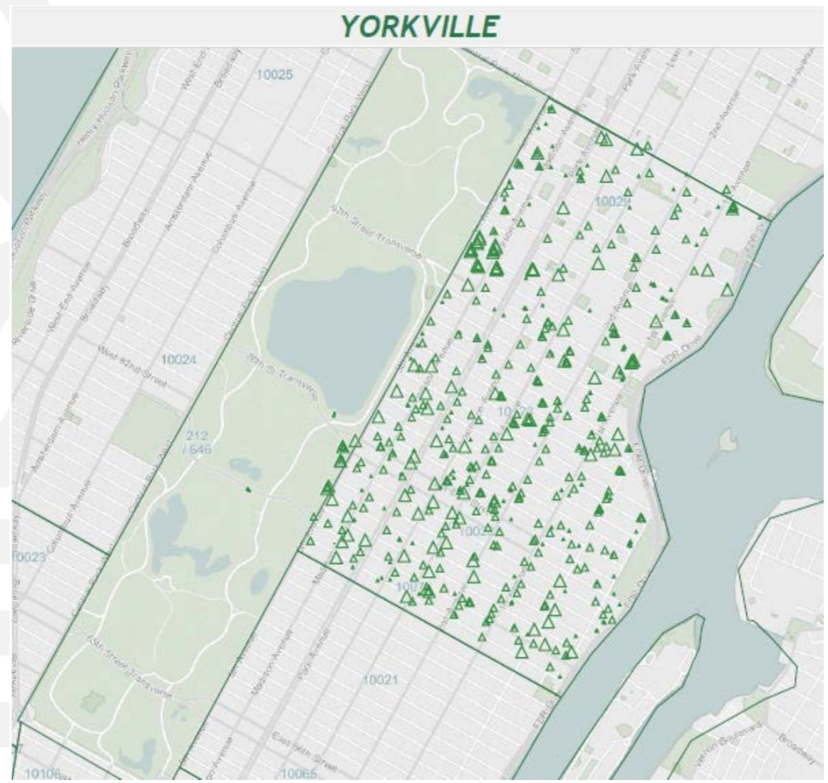
0.6 – **1.5** MW



map width: 5.44 miles, map height: 2.57 miles

Who’s doing it?

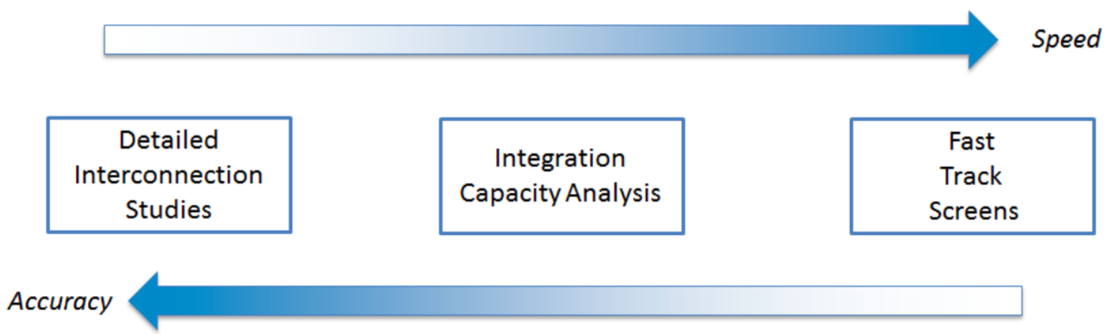
- ► California
- ► New York
- ► Minnesota
- ► Hawaii
- ► Pepco Holdings Inc.
- ► Unitil



ConEd, DSIP, 2016

Why?

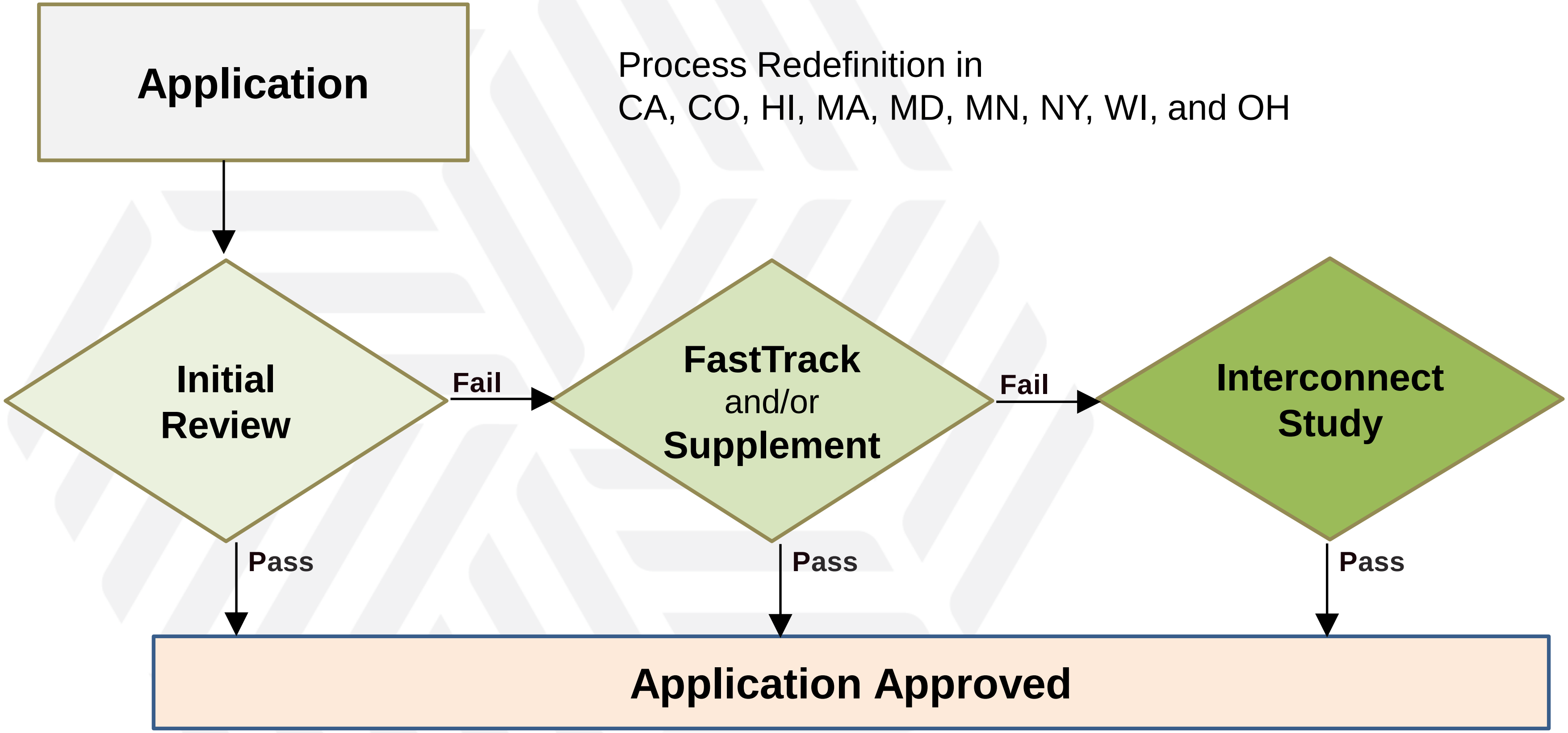
- ► Inform developers where DER can interconnect without system upgrades
- ► Streamline and potentially automate the interconnection process
- ► Inform distribution planning, such as where to proactively upgrade the grid to accommodate autonomous DER growth



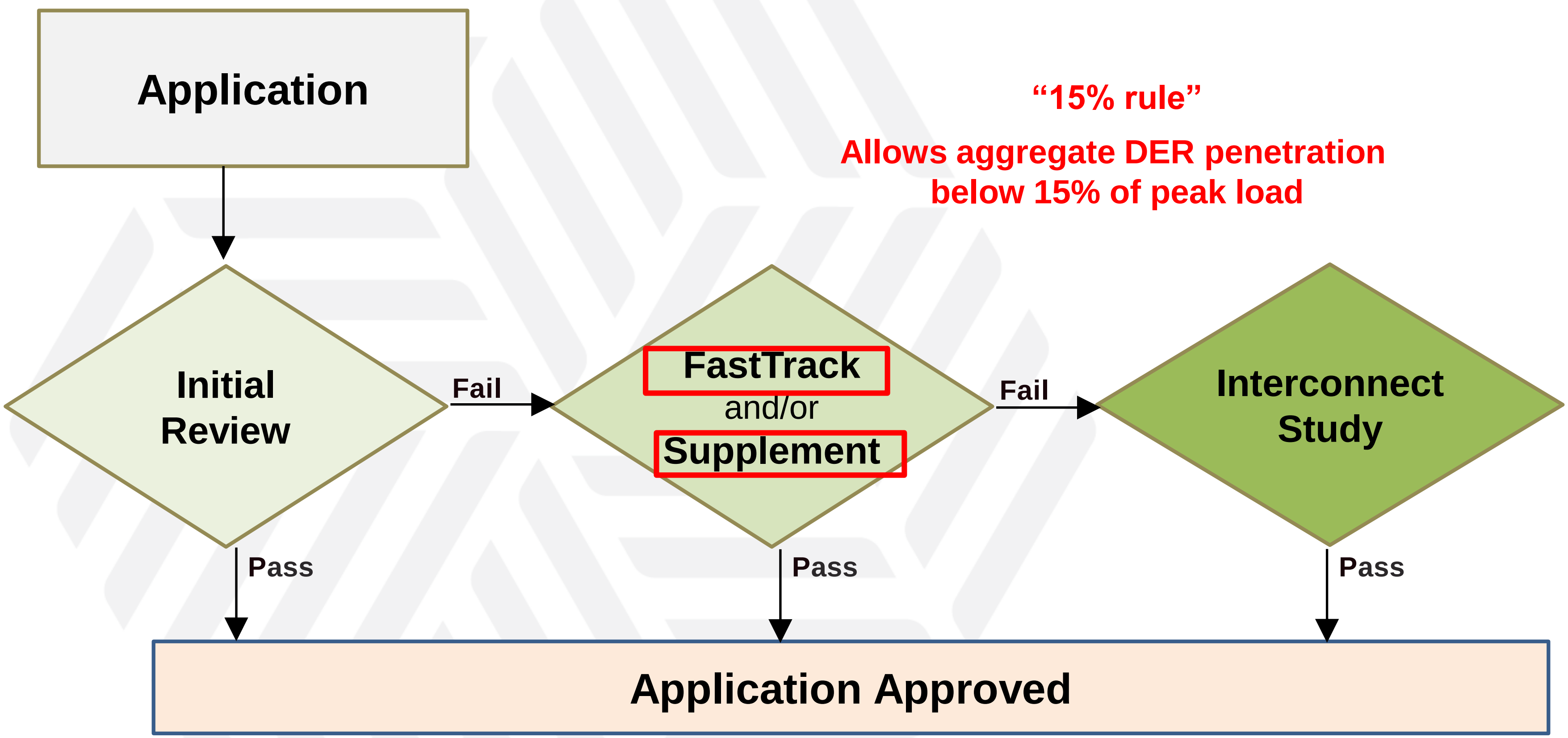
PG&E, DRP Webinar, 2015

Typical DER Interconnection Process

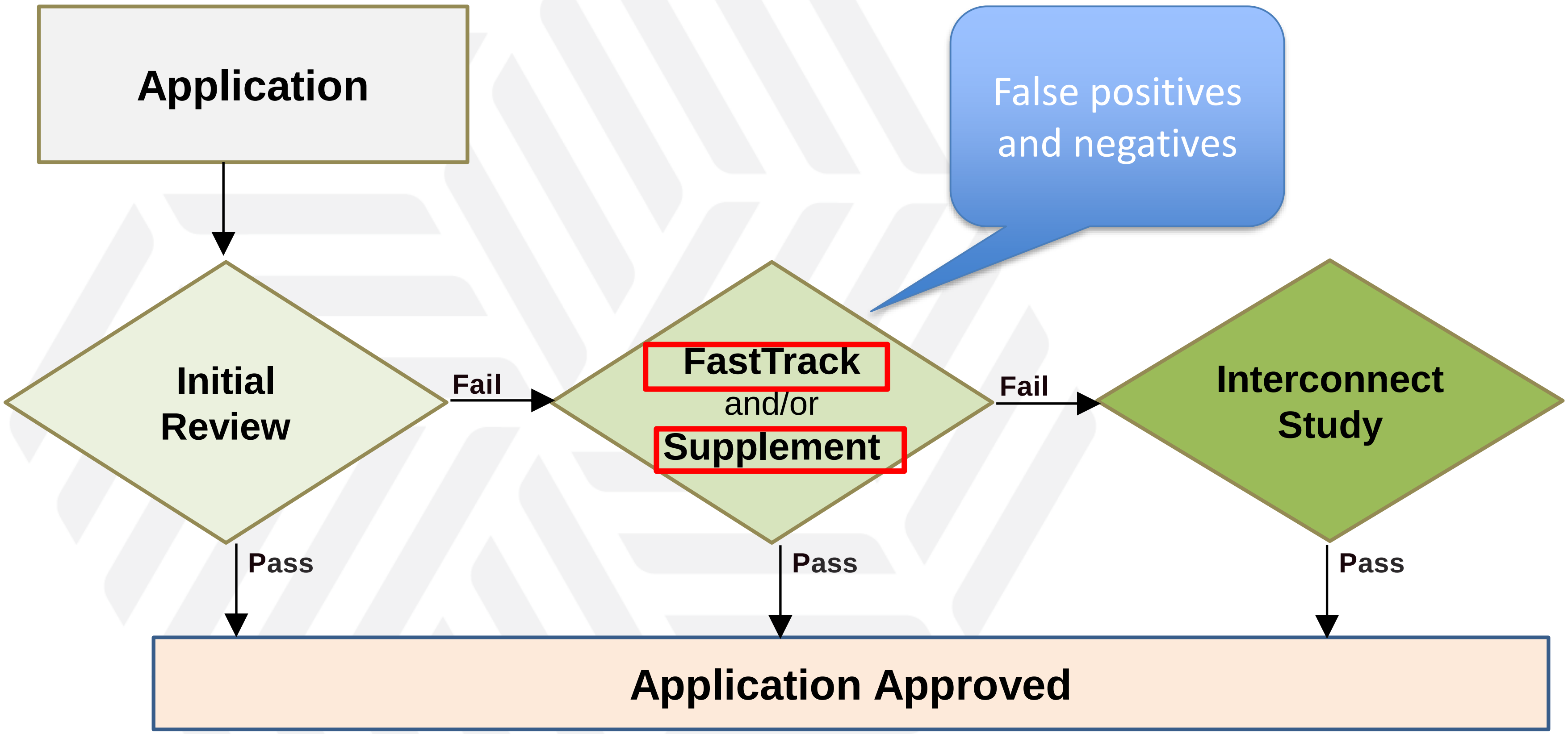
Process Redefinition in
CA, CO, HI, MA, MD, MN, NY, WI, and OH



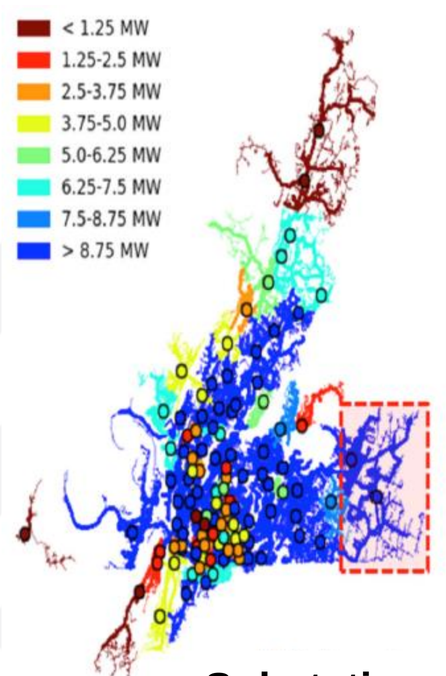
California DER Interconnection Process



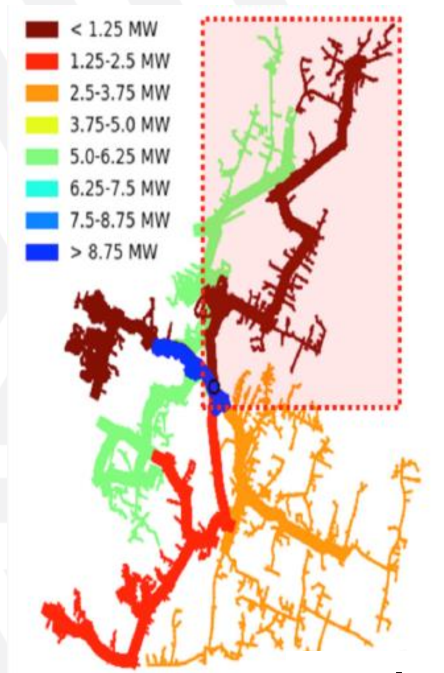
California DER Interconnection Process



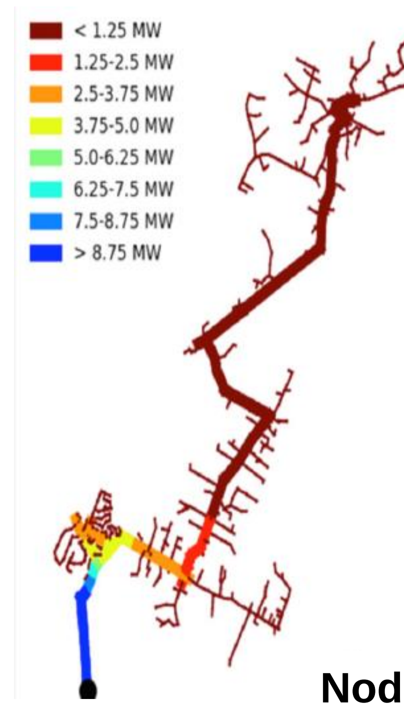
What level of Granularity is needed?



Substation



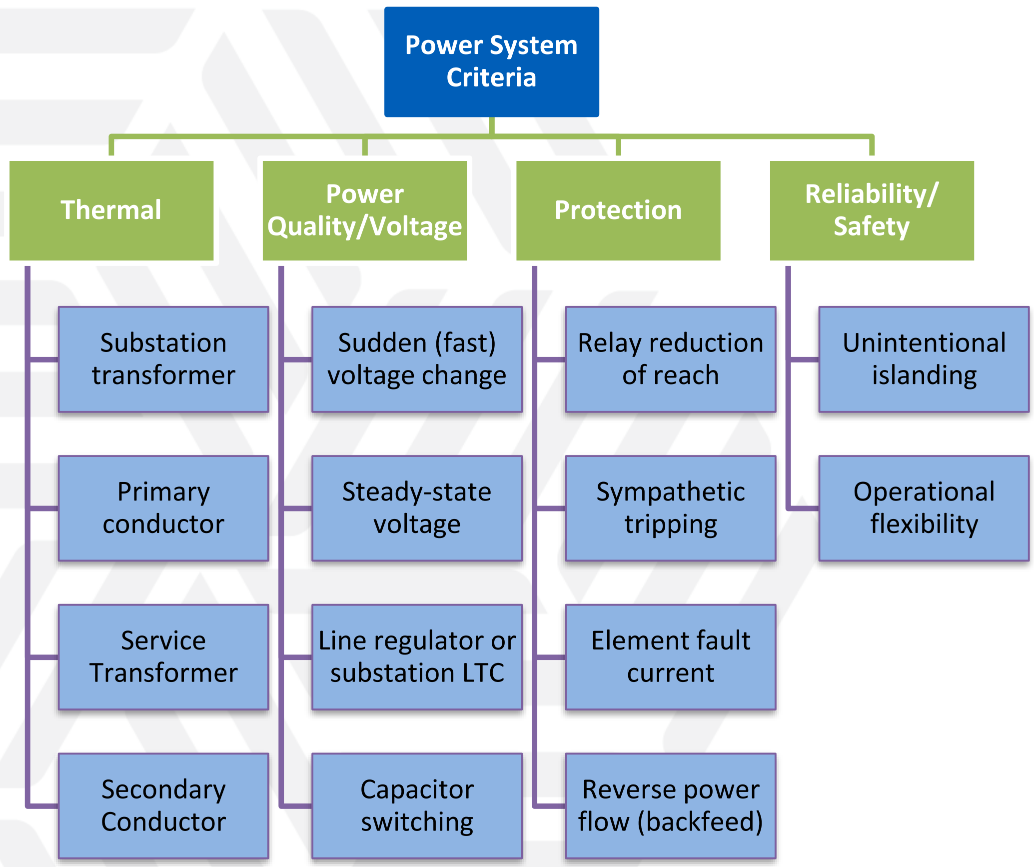
Feeder



Node

Defining a Roadmap for Successful Implementation of a Hosting Capacity Method for New York State, EPRI, Palo Alto, CA: 2016. 3002008848

Power System Criteria for Hosting Capacity



Integration of Hosting Capacity Analysis into Distribution Planning Tools, EPRI, Palo Alto, CA: 2015. 3002005793

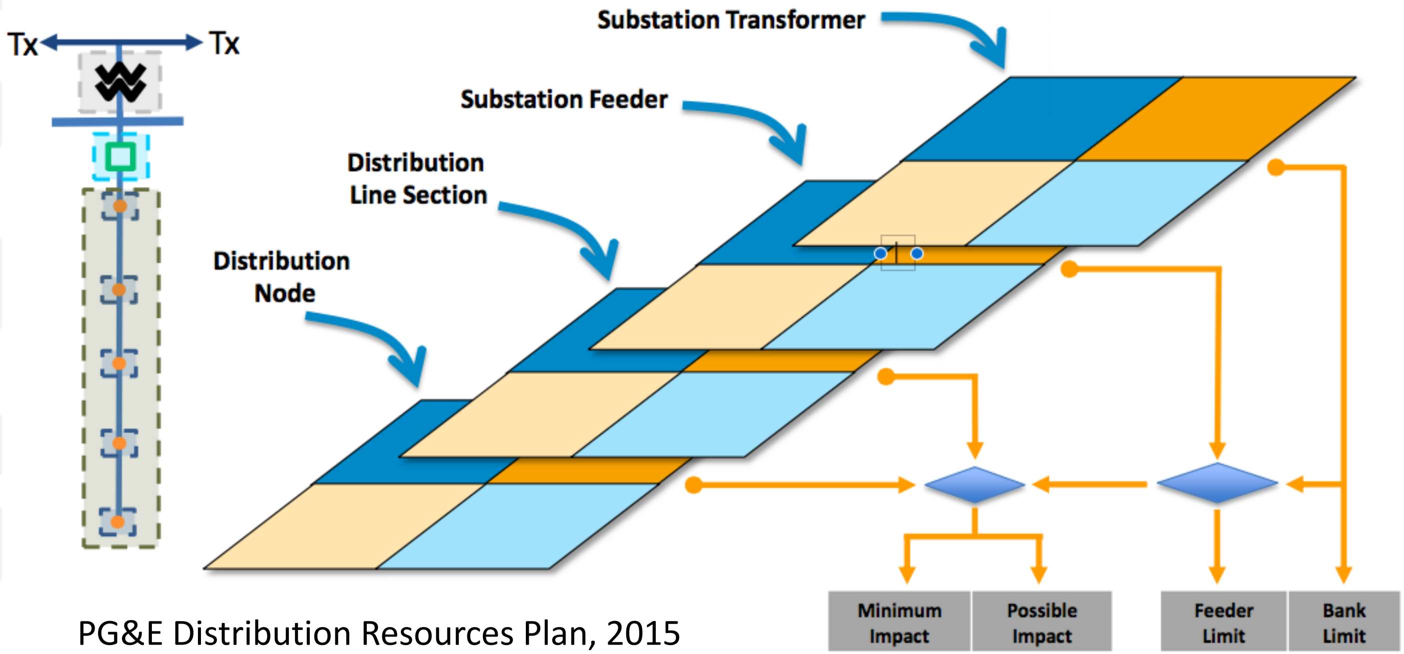
Examine power system limits at each relevant point in the system

Flexible Layered Framework

Each criteria limit is calculated for each layer independently and the most limiting values establish the integration capacity limit.

- SQL Server calculates final results for the whole dataset across selected DER types
- Utilizing SQL scripting enables collaboration with Integral Analytics to more easily incorporate methodology into commercial software

Thermal	Power Quality / Voltage
Protection	Safety / Reliability



PG&E Distribution Resources Plan, 2015

Typical DER Impacts Threshold Levels

Category	*Criteria*	*Basis*	*Flag*
Voltage	Overvoltage	Feeder voltage	≥ 1.05 Vpu
	Voltage Deviation	Deviation in voltage from no PV to full PV	≥ 3% at primary ≥ 5% at secondary ≥ ½ band at regulators
	Unbalance	Phase voltage deviation from average	≥ 3%
Loading	Thermal	Element loading	≥ 100% normal rating
Protection	Total Fault Contribution	Total fault current contribution at each sectionalizing device	≥ 10% increase
	Forward Flow Fault Contribution	Forward flow fault current contribution at each sectionalizing device	≥ 10% increase
	Sympathetic Breaker Tripping	Breaker zero sequence current due to an upstream fault	≥ 150A
	Breaker Reduction of Reach	Deviation in breaker fault current for feeder faults	≥ 10% decrease
	Breaker/Fuse Coordination	Fault current increase at fuse relative to breaker current increase	≥ 100A increase
	Anti-Islanding	PV beyond each sectionalizing device	≥ 50% minimum load
Power Quality	Individual Harmonics	Harmonic magnitude	≥ 3%
	THDv	Total harmonic voltage distortion	≥ 5%
Control	Regulator	Increased duty	> basecase+1
	Capacitor	Increased duty	> basecase+1

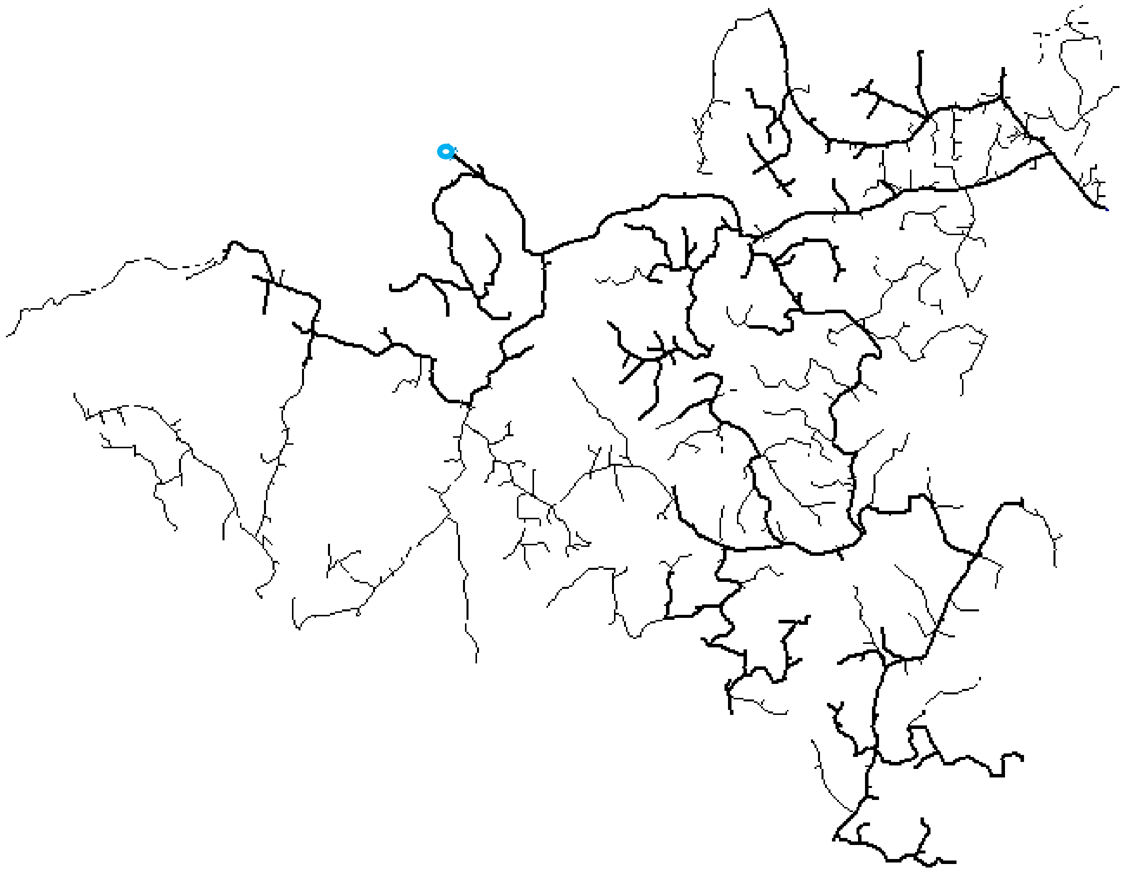
Typical Steady-State Voltage Threshold Levels

Category	Criteria	Basis	Flag
Voltage	Overvoltage	Feeder voltage	≥ 1.05 Vpu
	Voltage Deviation	Deviation in voltage from no PV to full PV	≥ 3% at primary ≥ 5% at secondary ≥ ½ band at regulators
	Unbalance	Phase voltage deviation from average	≥ 3%
Loading	Thermal	Element loading	≥ 100% normal rating
Protection	Total Fault Contribution	Total fault current contribution at each sectionalizing device	≥ 10% increase
	Forward Flow Fault Contribution	Forward flow fault current contribution at each sectionalizing device	≥ 10% increase
	Sympathetic Breaker Tripping	Breaker zero sequence current due to an	≥ 150A
	Breaker Reduction of Reach	der	≥ 10% decrease
	Breaker/Fuse Coordination		≥ 100A increase
	Anti-Islanding		≥ 50% minimum load
Power Quality	Individual Harmonics	Harmonic magnitude	≥ 3%
	THDv	Total harmonic voltage distortion	≥ 5%
Control	Regulator	Increased duty	> basecase+1
	Capacitor	Increased duty	> basecase+1

ANSI C.84 limits

Nominal Voltage (V)	Service Voltage (V)	
	Min	Max
120	114	126

We don't know where the PV will be interconnected

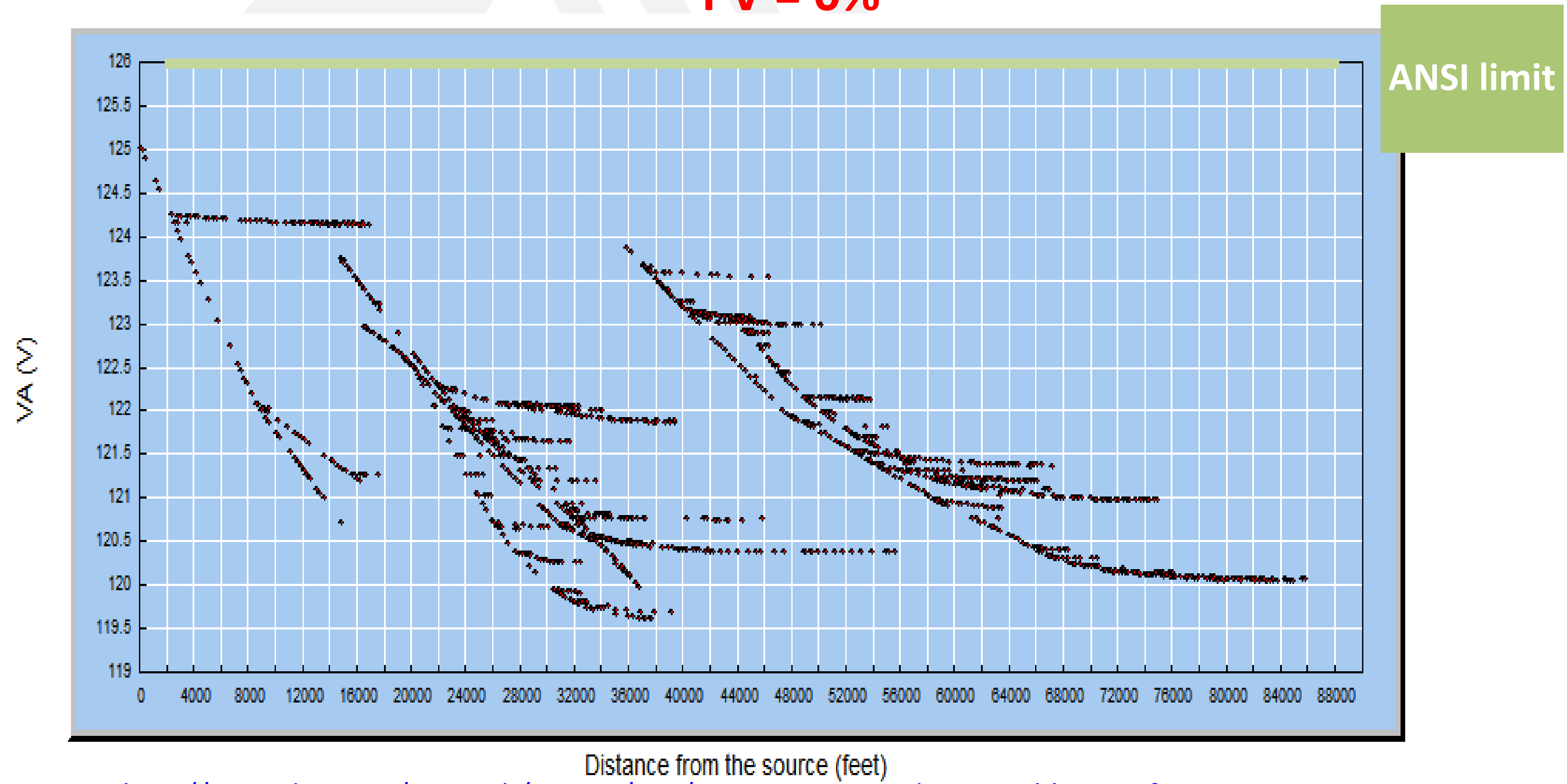


There are 4000-5000 nodes on this feeder where PV could be interconnected

PV location makes a huge difference

Feeder voltage profile

PV = 0%

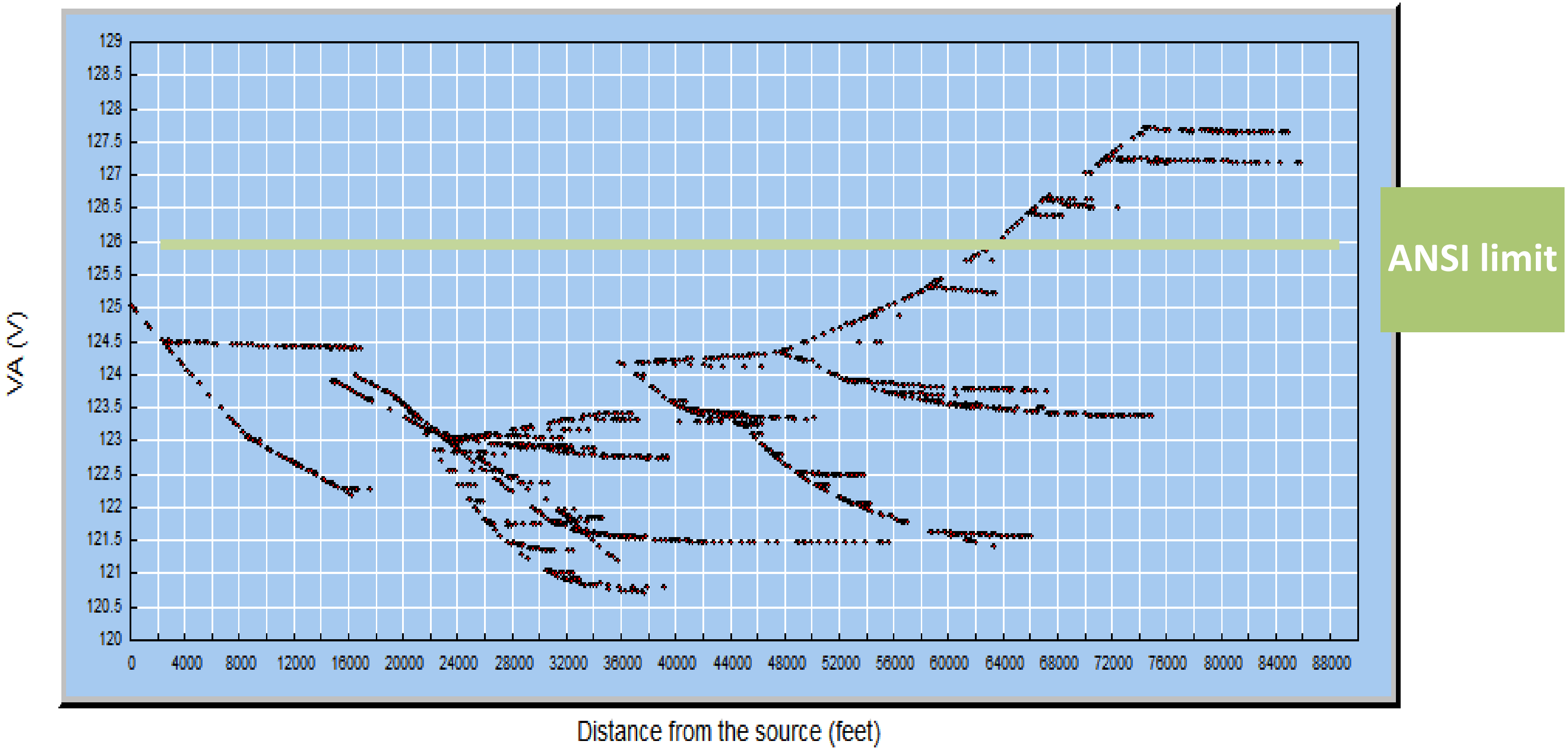


DSTAR, http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders

PV location makes a huge difference

Feeder voltage profile

Single PV = 20%

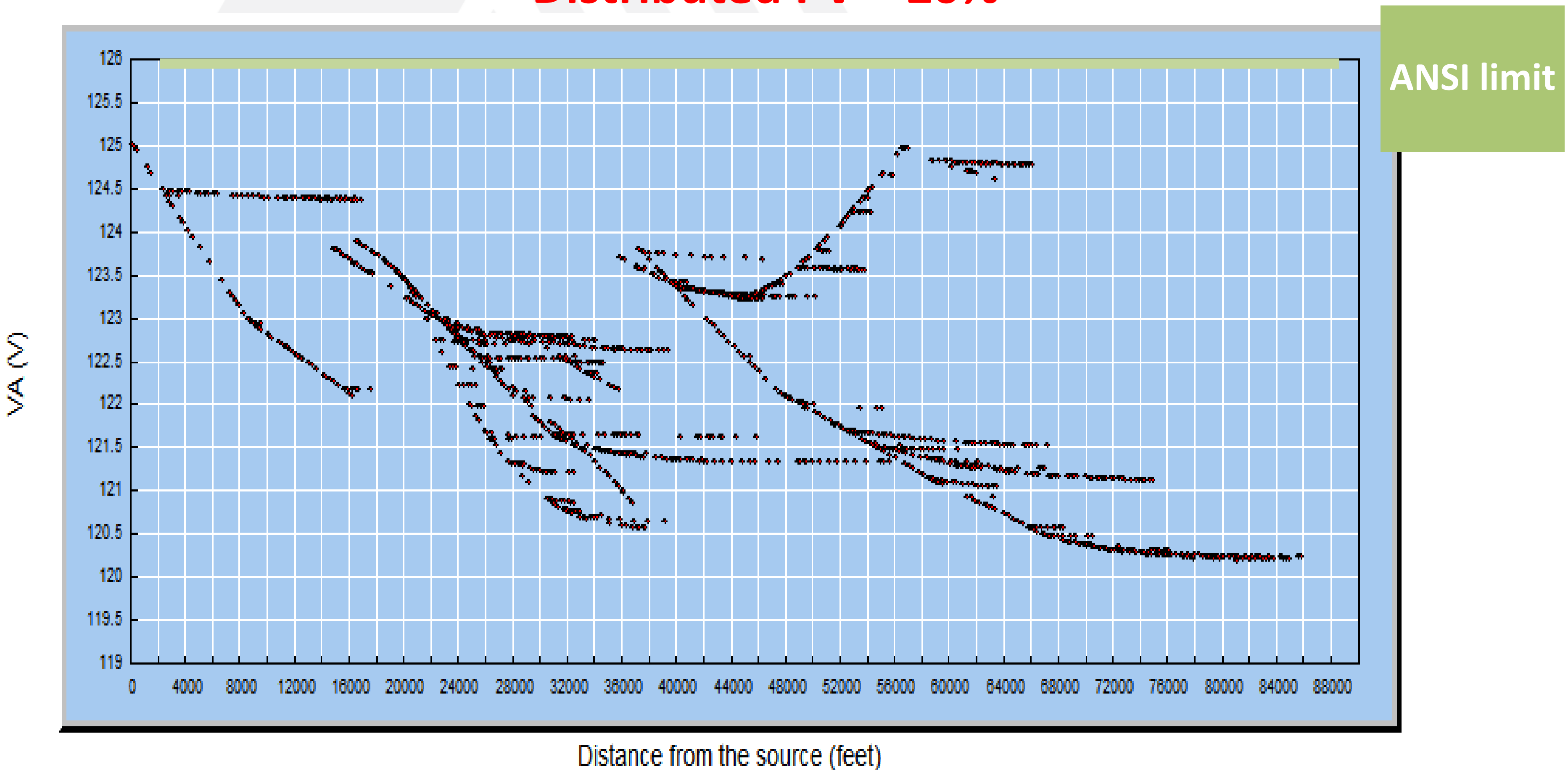


DSTAR, http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders

PV location makes a huge difference

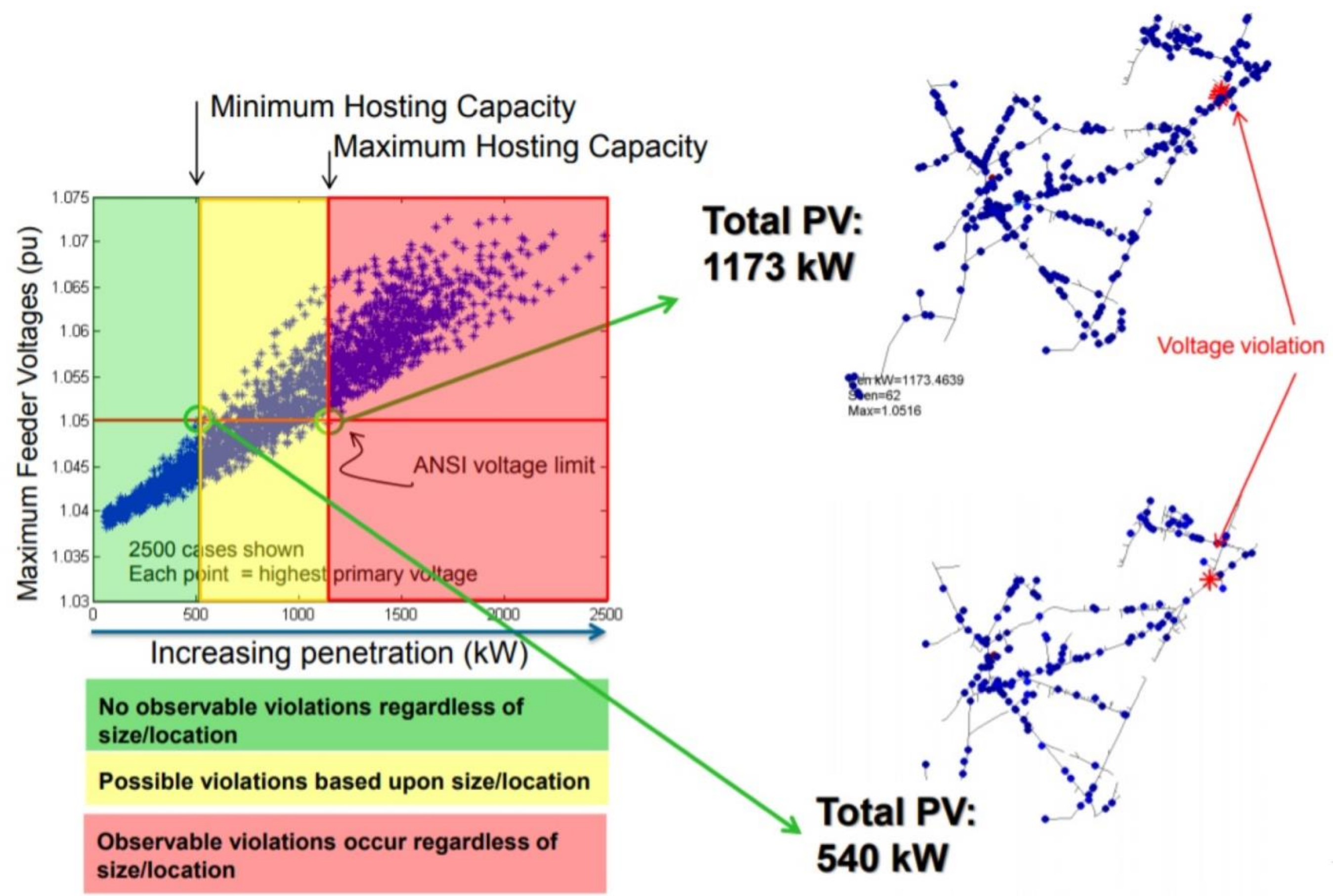
Feeder voltage profile

Distributed PV = 20%



DSTAR, http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders

Hosting capacity range for overvoltage violation

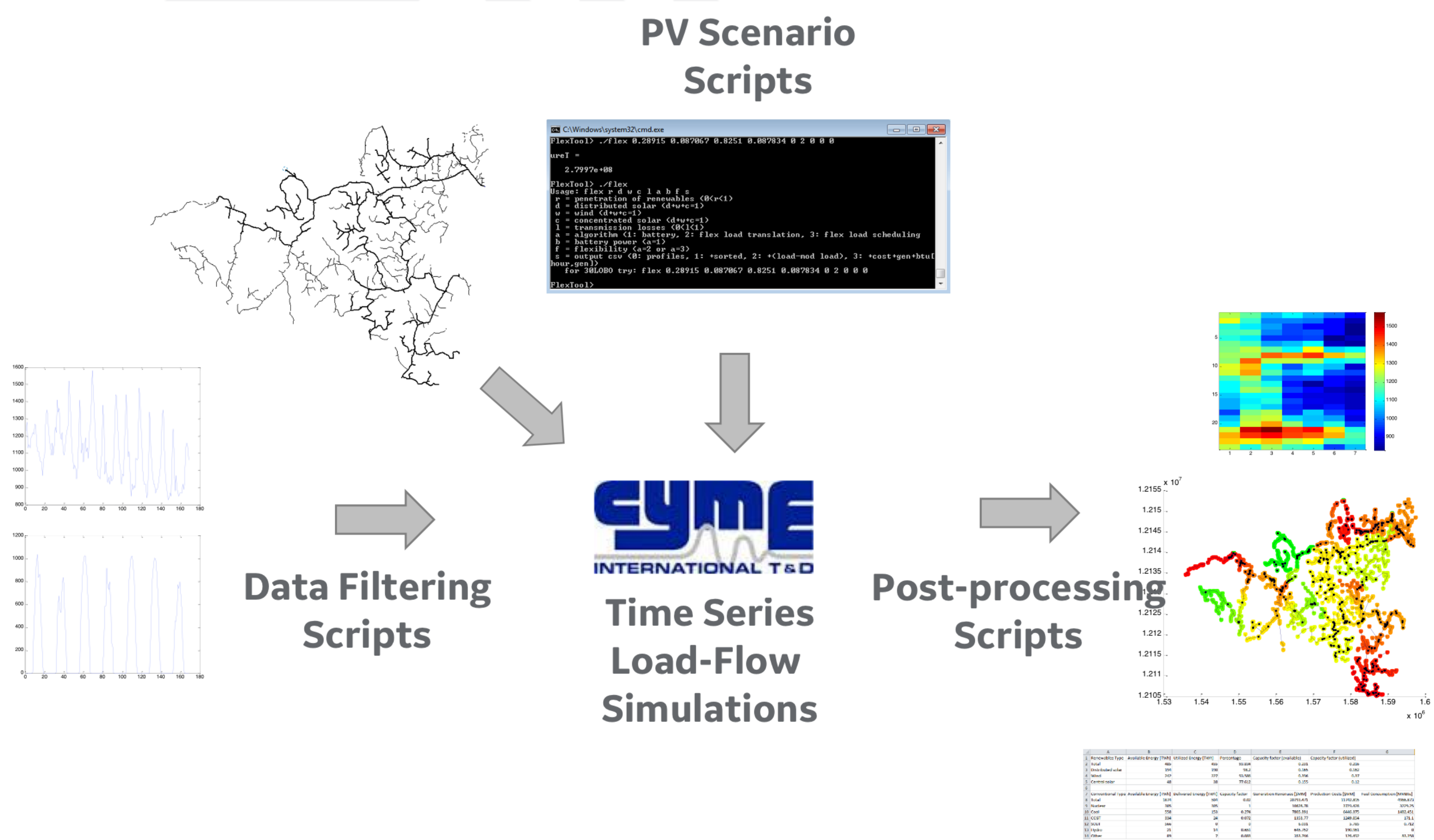


EPRI, *Stochastic Analysis to Determine Feeder Hosting Capacity for Distributed Solar PV, Palo Alto, CA 2012.*

Methodologies

Detailed Analysis	Power flow simulations conducted at each node until violations occur, e.g., SCE, SDG&E. Stochastic analysis uses many simulations (e.g., different sizes in different locations) to give uncertainty range.
Streamlined	Simplified algorithms for each power system limitation to estimate when violations occur, e.g., PG&E
Shorthand Equations	Very simple calculation method

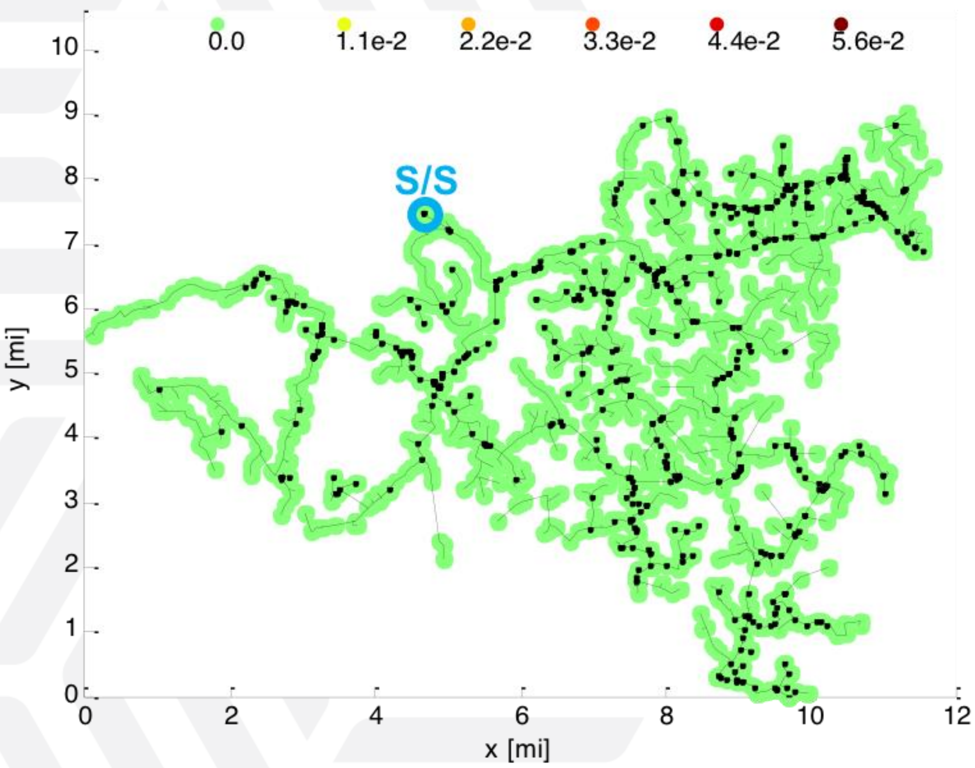
Detailed Analysis



DSTAR, http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders

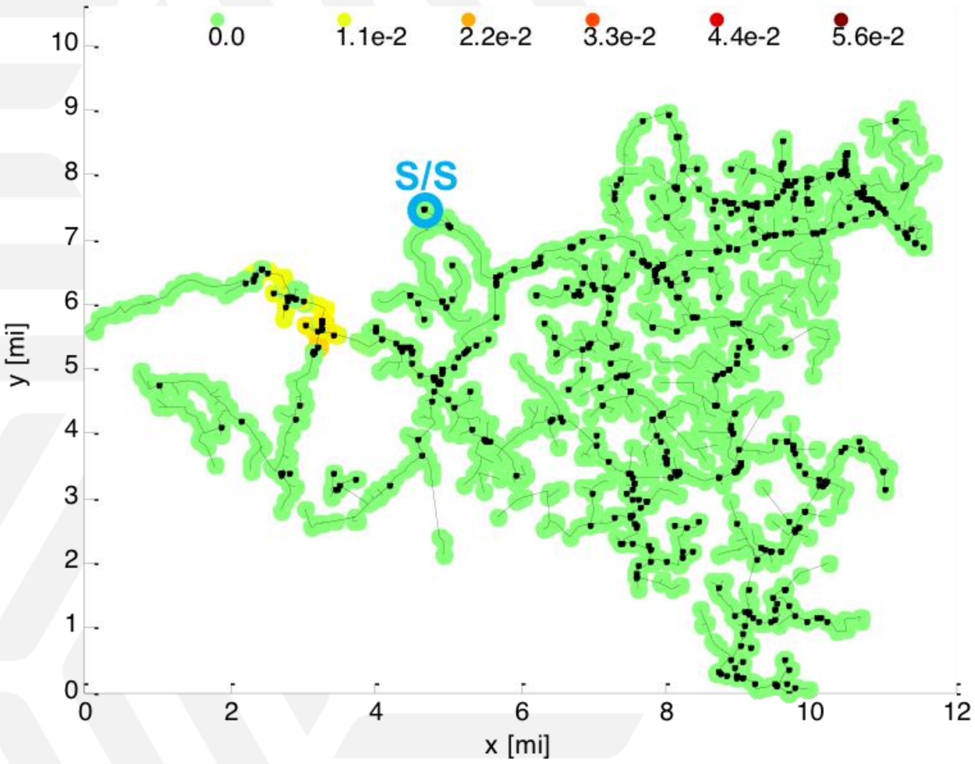
Voltage violation with PV=0%

Likelihood of over-voltage 11am – 2pm



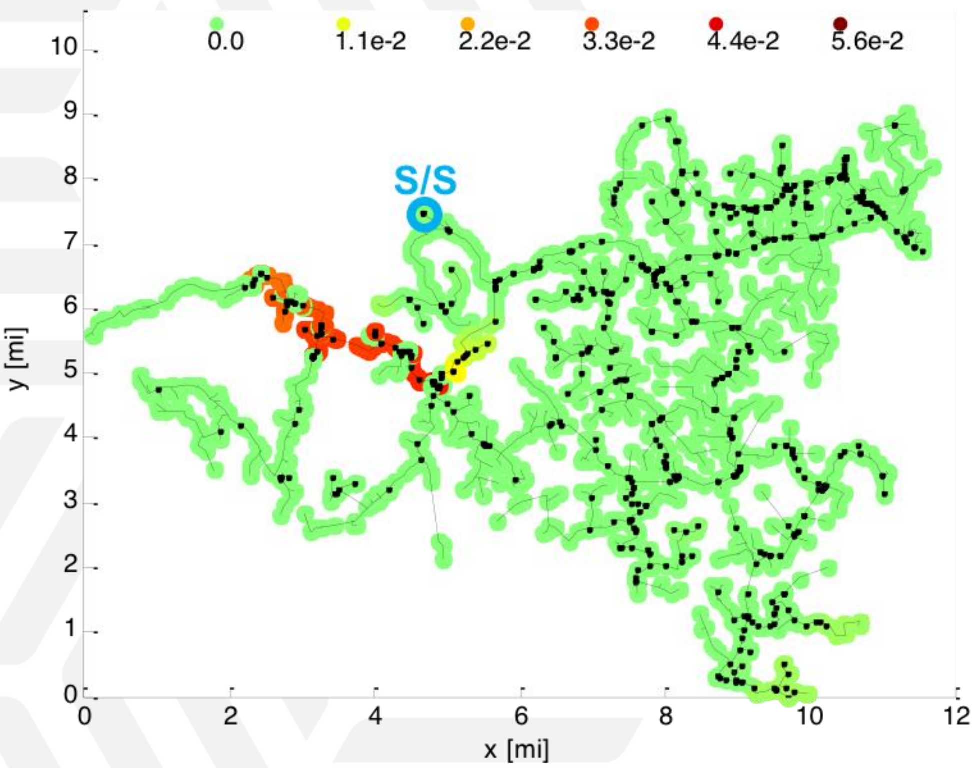
Voltage violation with PV=2%

Likelihood of
over-voltage
11am – 2pm



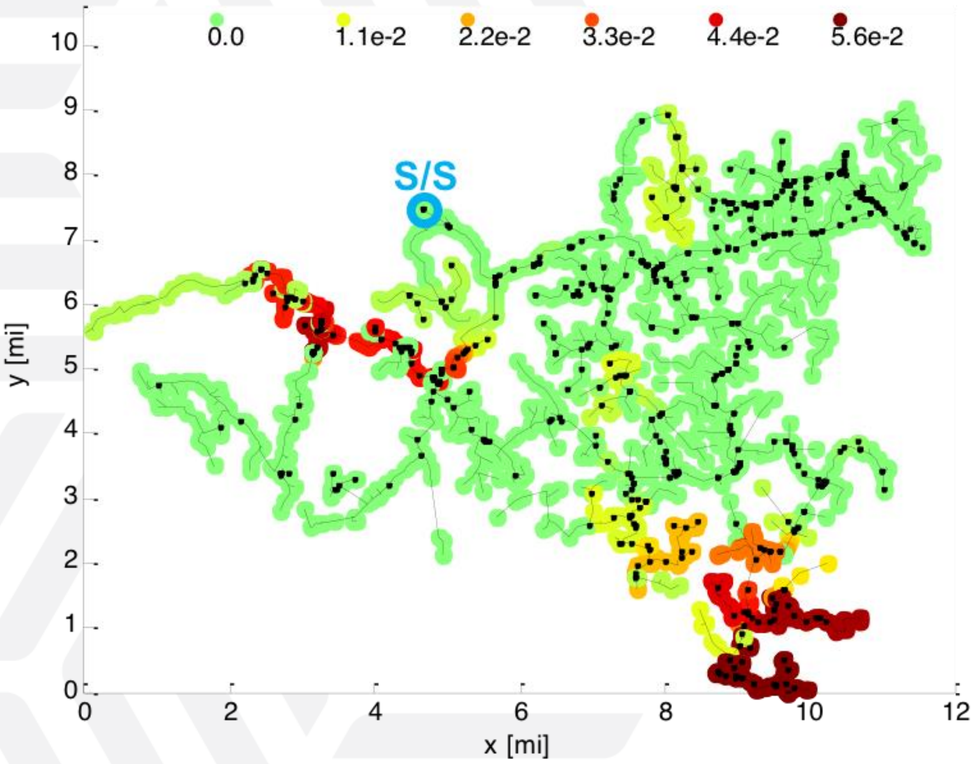
Voltage violation with PV=6%

Likelihood of
over-voltage
11am – 2pm

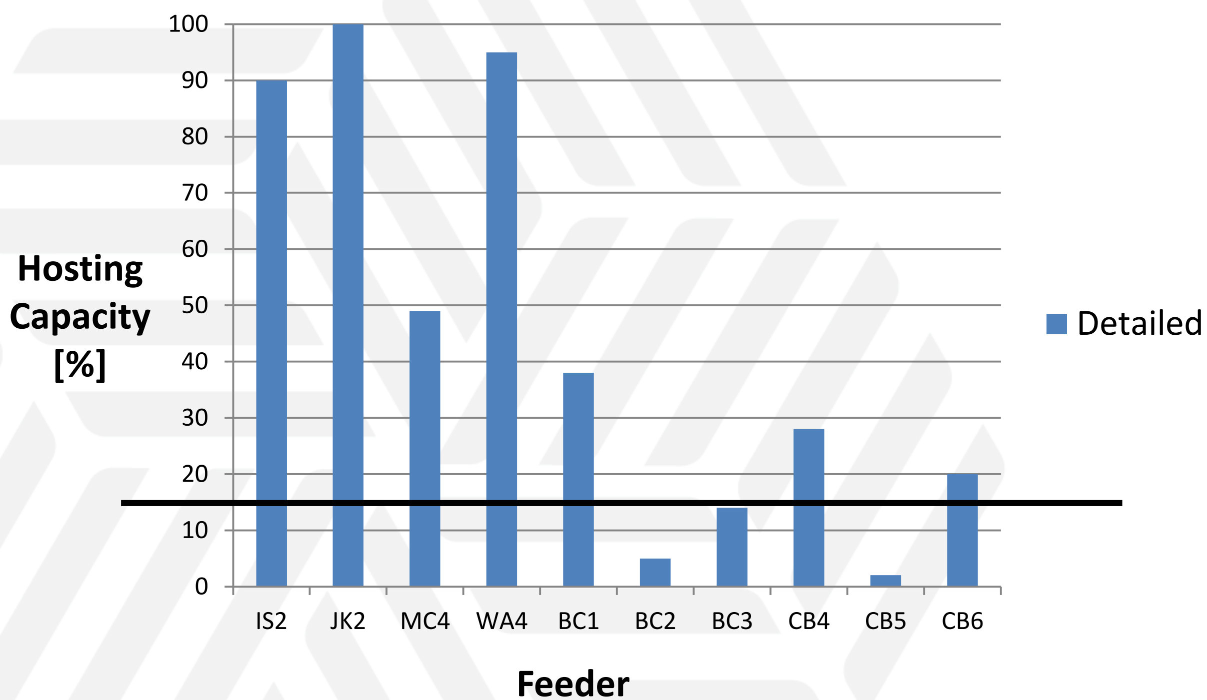


Voltage violation with PV=10%

Likelihood of over-voltage 11am – 2pm

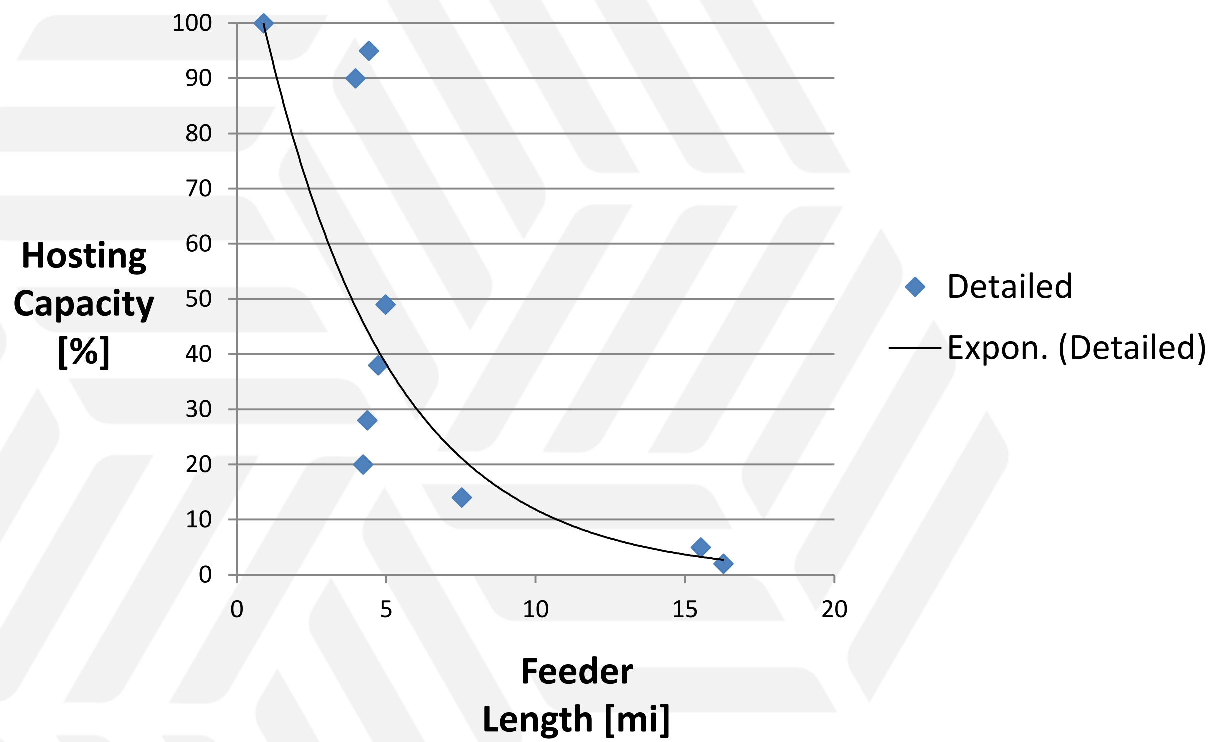


Detailed Analysis - Hosting Capacity



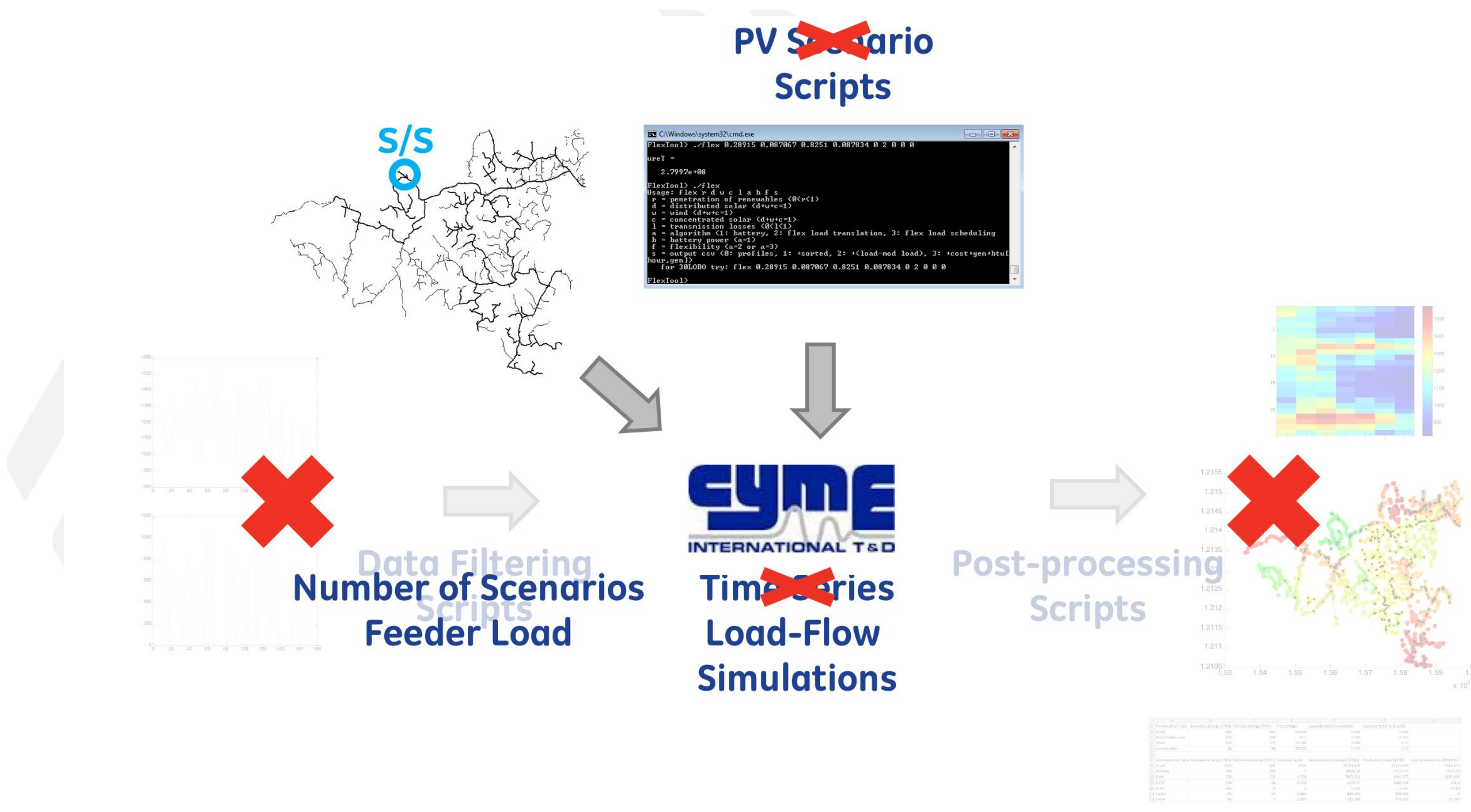
DSTAR, http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders

Feeder Length is Critical



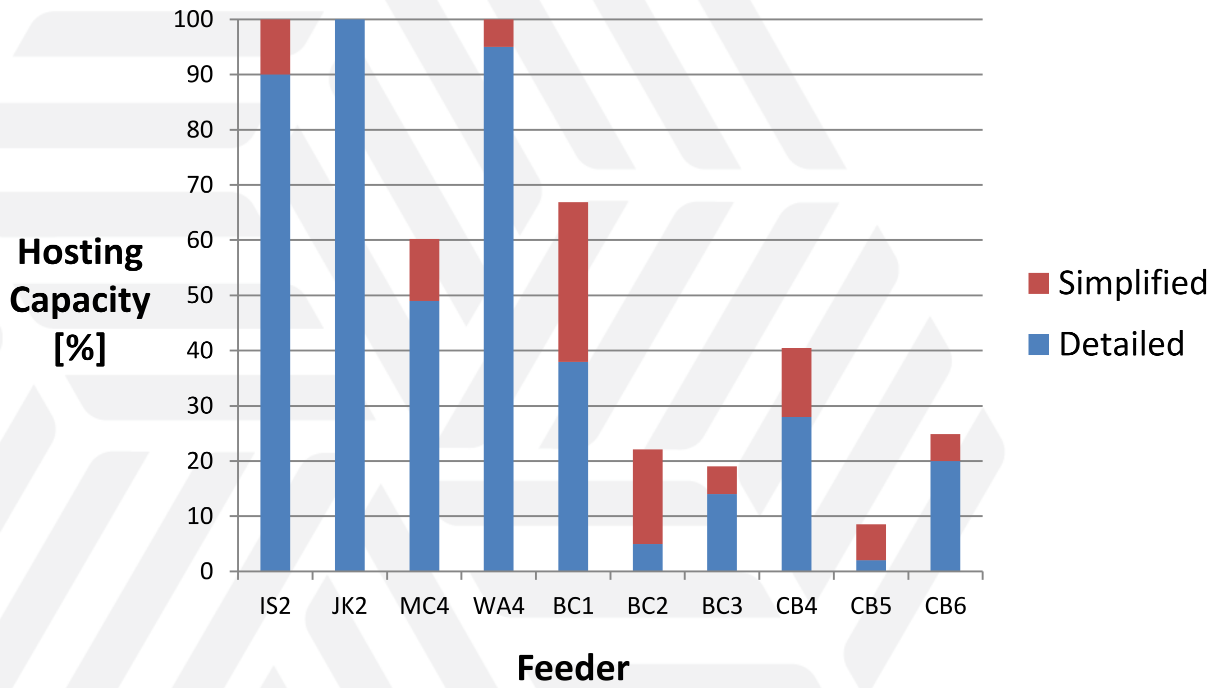
DSTAR, http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders

Simplified Analysis



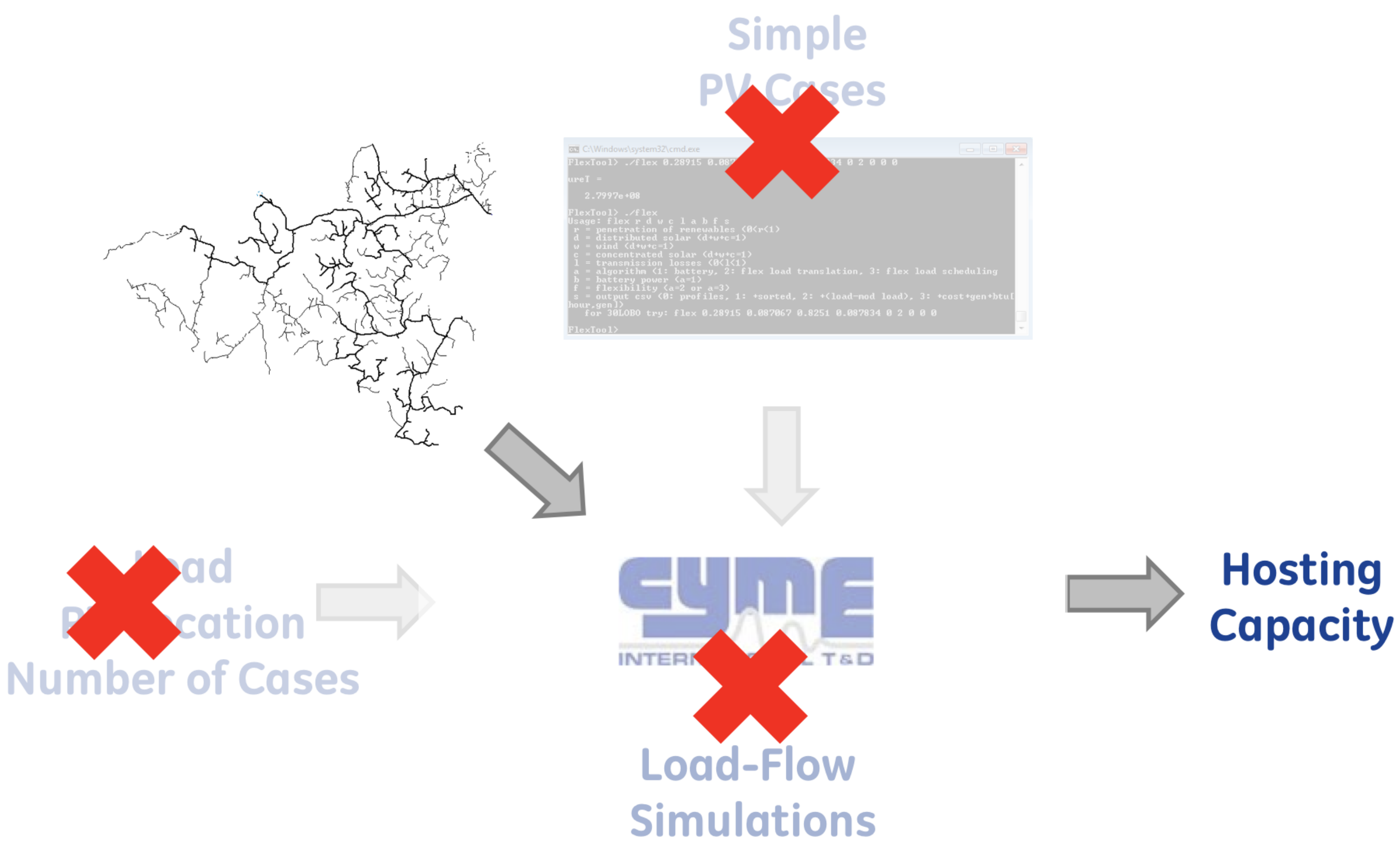
DSTAR, http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders

Simplified Analysis - Hosting Capacity

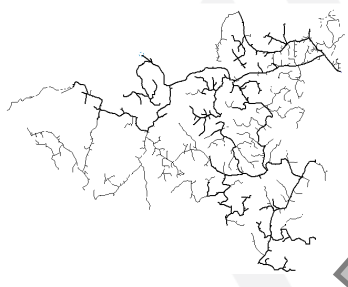


DSTAR, http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders

Shorthand Equations – from the California Solar Initiative



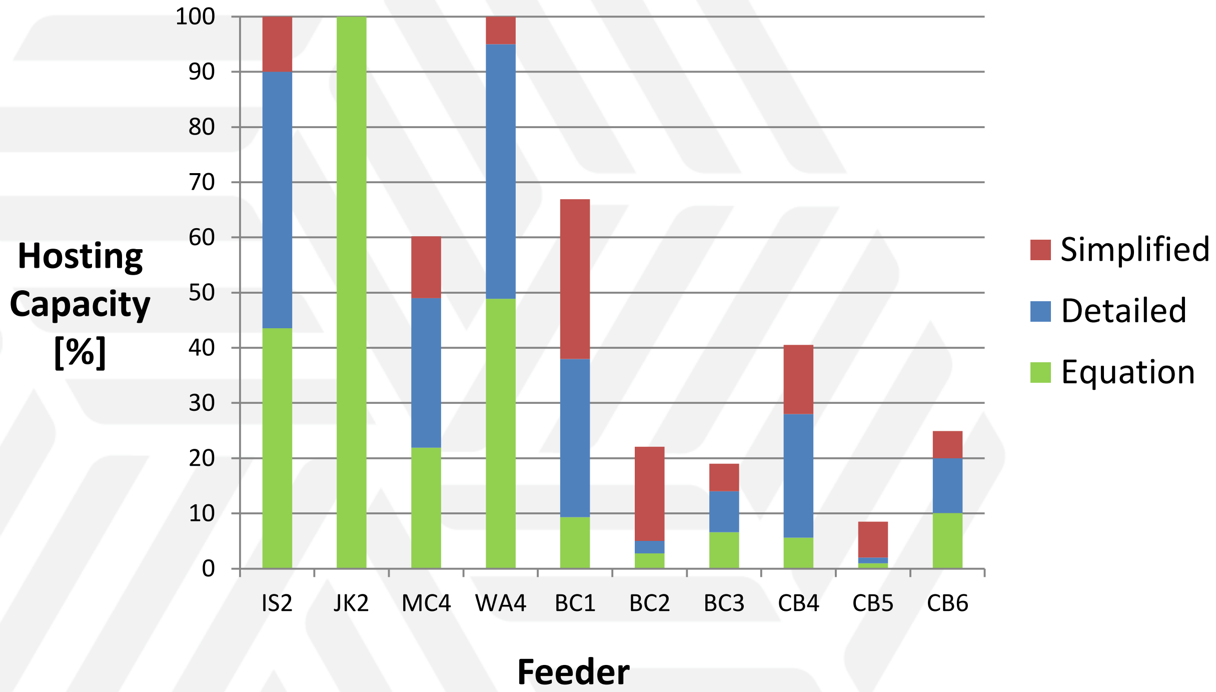
Shorthand Equations – Approach



Voltage Profile → **Shorthand Equations** → **Hosting Capacity**

EPRI, *Alternatives to the 15% Rule*, Dec. 2015

Shorthand Equations - Hosting Capacity



SCE Integration Capacity Analysis

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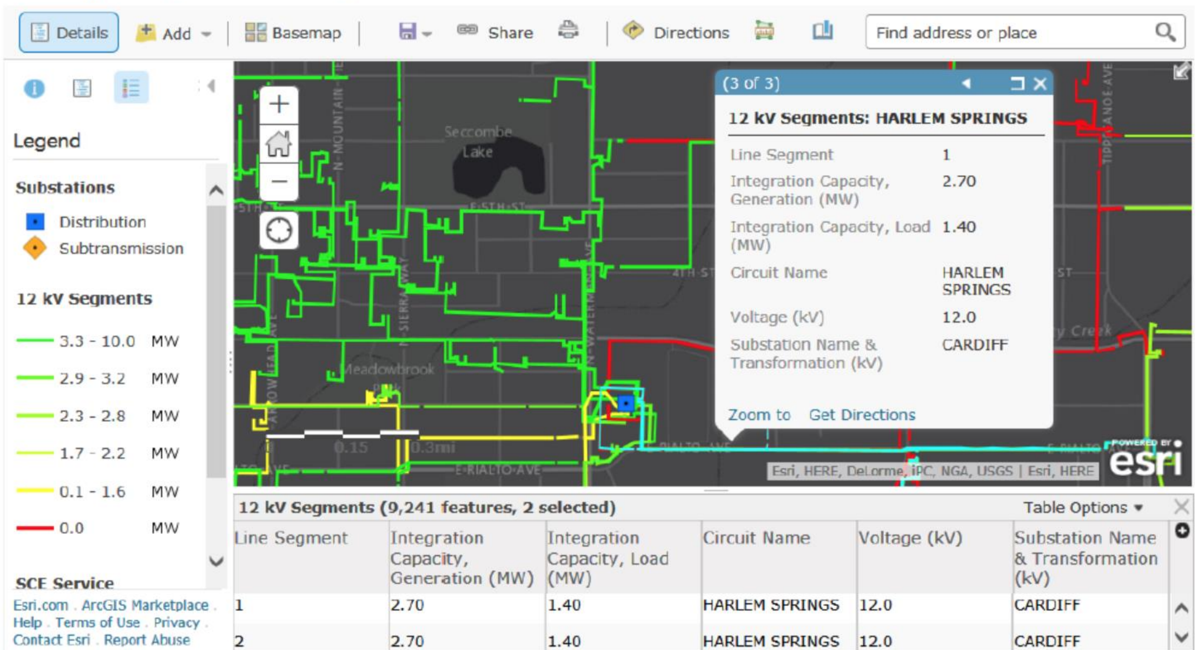
Distributed Energy Resource Interconnection Maps (DERiM)



SCE DERIM: on.sce.com/derim

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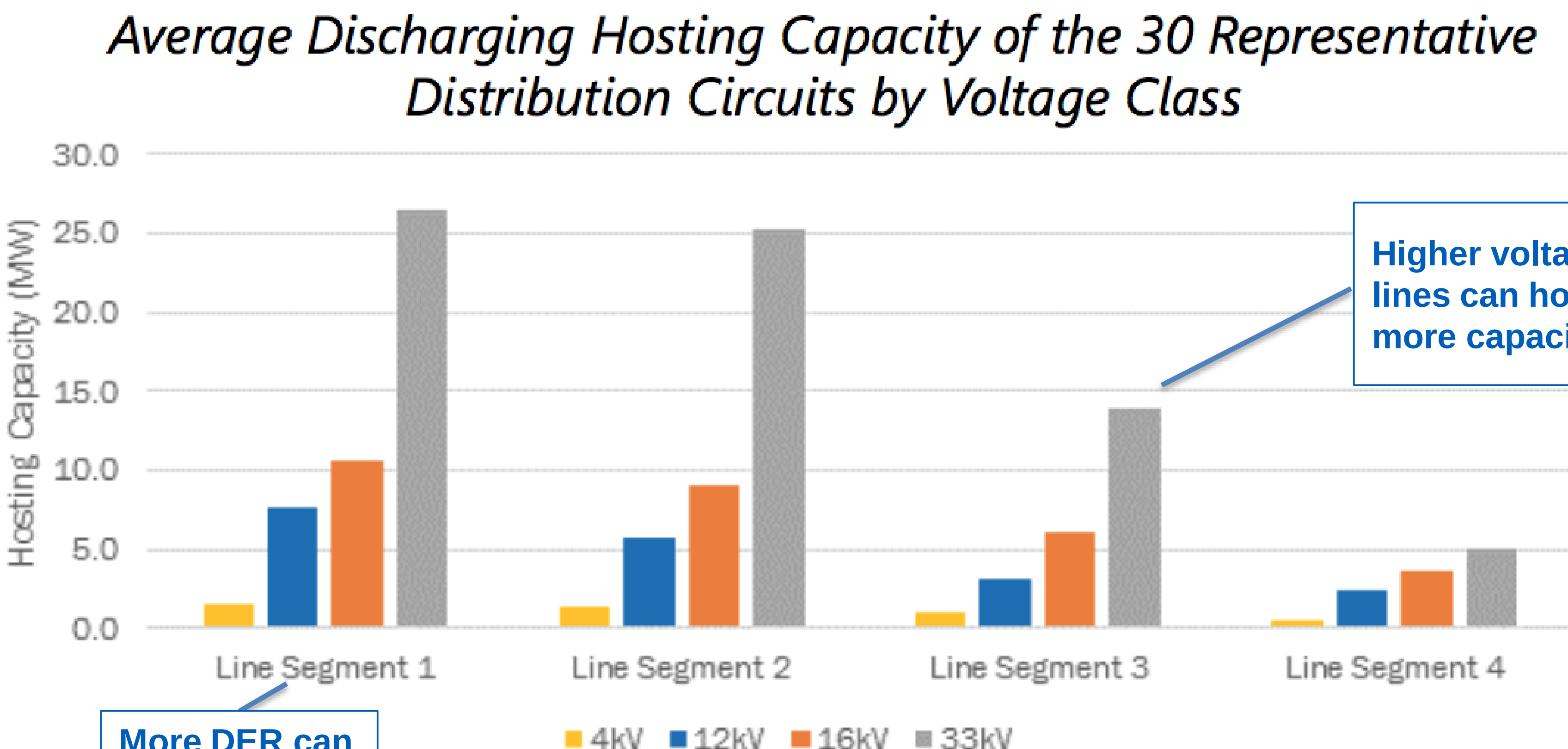
SOUTHERN CALIFORNIA EDISON

Southern California Edison, Distribution Resources Plan, 2015

Hosting Capacity in SCE for energy producing DERs



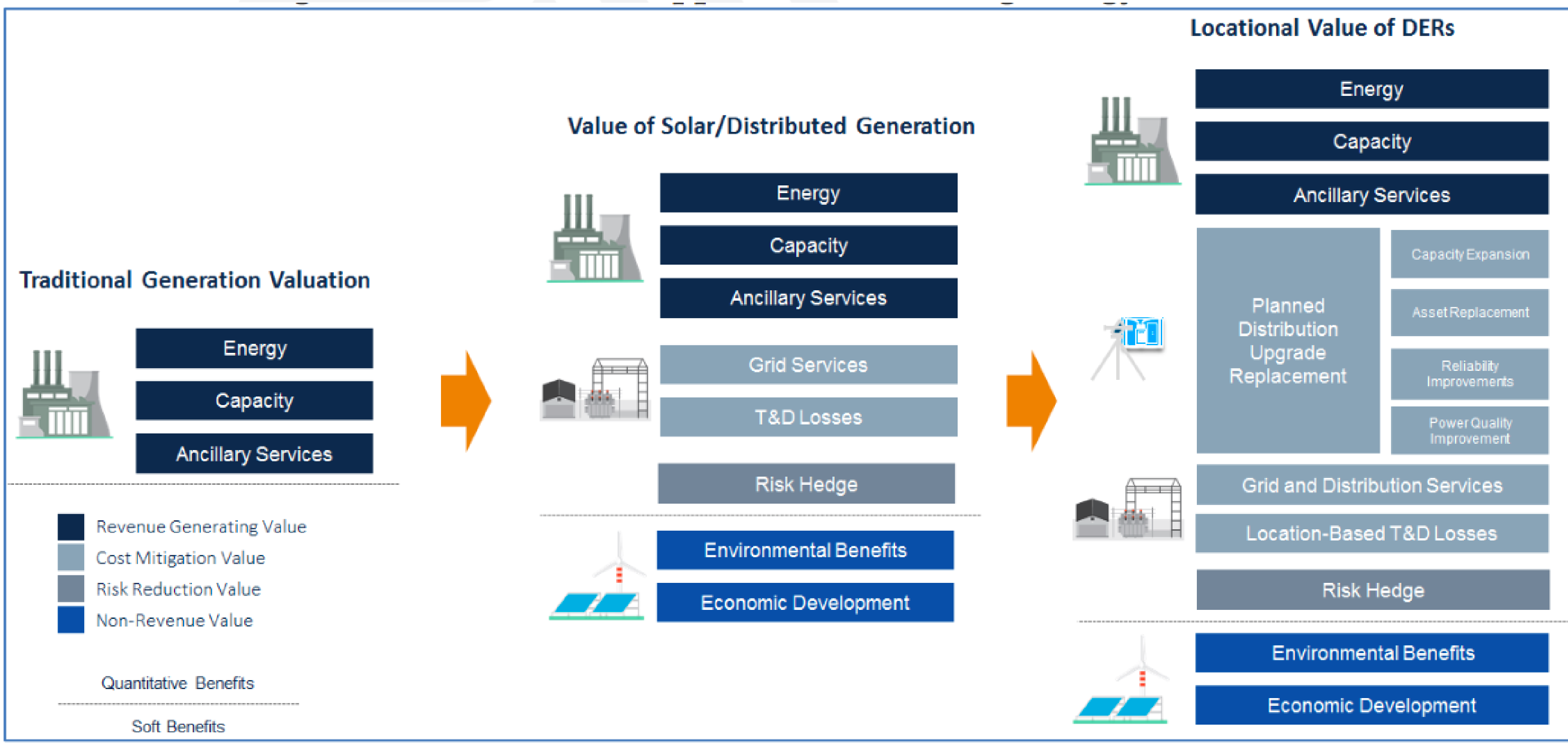
Higher voltage lines can host more capacity

More DER can be hosted closer to the substation

SCE, DRP, 2015

Locational Net Benefits

Benefits of DERs



Ben Kellison, "Unlocking the Locational Value of DER 2016: Technology Strategies, Opportunities, and Markets," January 2016,

Why LNBA?

- ► Public tool and heat map
- ► Prioritization of candidate distribution deferral opportunities
- ► Determine cost-effectiveness, compare projects
- ► Inform compensation or incentives

Beware: Pitfalls of calculating locational net benefits

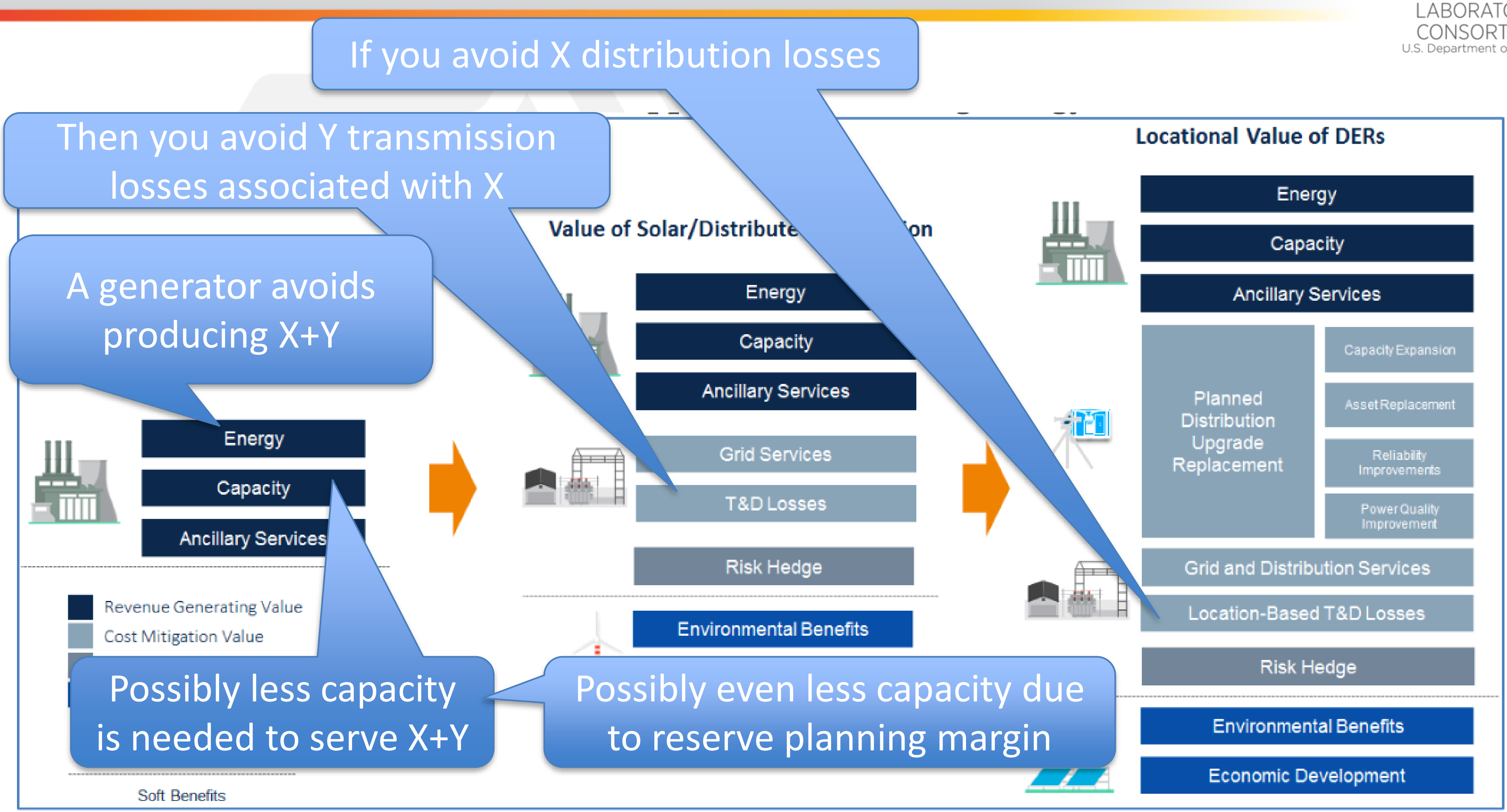
► Benefits vary
- By technology
- By time (of day, season, etc)
- By location (LMP node, feeder, location on feeder)

► DER may provide many services/benefits – be careful to avoid double-counting

► What are you avoiding? What is the business-as-usual path?

► Average avoided cost estimates are easy and transparent but lack rigor of modeling actual hourly, location-based operations. Get the large value streams correct.

These value streams have ripple effects



Ben Kellison, "Unlocking the Locational Value of DER 2016: Technology Strategies, Opportunities, and Markets," January 2016,

Calculate the localized impacts first

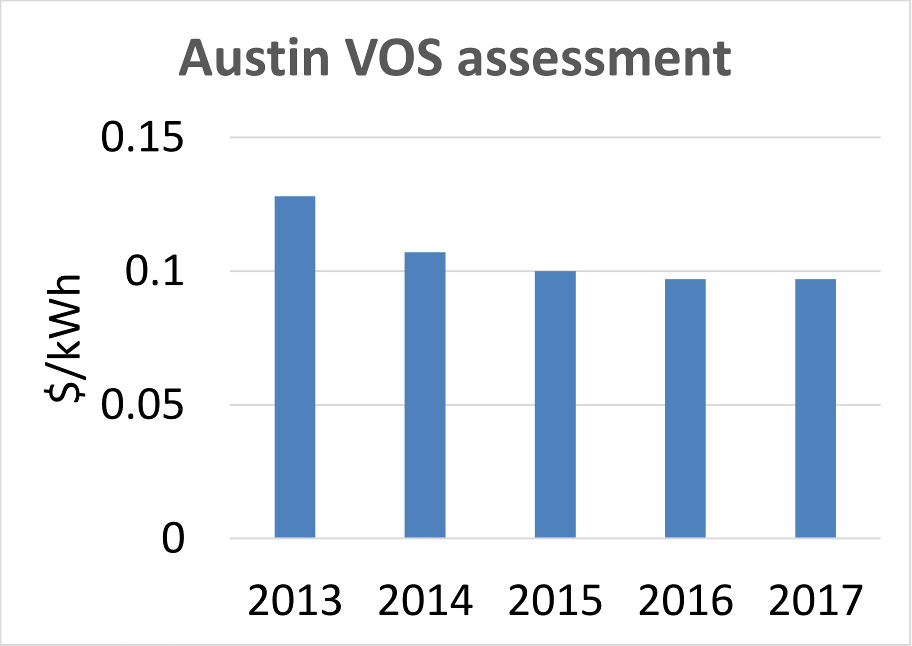
Avoided energy

DER may avoid fuel and O&M costs from the marginal generator

- ► DER may avoid the energy it produces plus the T&D losses associated with that production
- ► Options for calculation:
  - Assume marginal generator(s), heat rate(s)
  - Historical LMPs, forward prices
  - Locational marginal price at a node – production cost modeling simulates unit commitment and economic dispatch for each hour of the year

Beware: Declining value of Solar

- ► As more MW of solar are added, the value of the energy and capacity decline.
- ► If a tariff is not locked in for long-term, this is risky for solar customers.
- ► Storage can mitigate the declining value of solar by producing at peak, even as peak shifts to later hours.
- ► Solar PV production degrades (0.5%/year) over time.



Avoided capacity

DER may avoid the need for additional generation capacity

- ► DER may avoid capacity equivalent to its capacity value plus some amount due to avoided T&D losses. It may also avoid additional capacity that would be needed for the planning reserve margin.
- ► Options for calculation:
  - Average capacity factor of DER during peak net-load hours
  - Approximations to effective load-carrying capability without iterations
  - Effective load-carrying capability analysis with iterative loss-of-load probability calculation

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DER may avoid transmission losses

- ► DER may avoid transmission losses associated with the energy production of the DER plus avoided distribution losses
- ► Options for calculation:
  - Average loss rate – overestimates losses
  - Marginal loss rates with diurnal and monthly profiles – losses are higher during peak flows
  - Power flow modeling – production cost models may estimate transmission losses

Distribution losses

DER may avoid distribution losses since energy is generated at the point of consumption.

- ► High penetrations of DER could lead to reverse power flow and increased distribution losses
- ► Options for calculation:
  - Average loss rate – overestimates losses
  - Marginal loss rates with diurnal and monthly profiles – losses are higher during peak
  - Power flow modeling of feeder for selected (peak load, peak PV, etc) periods or time-series simulations. Computationally challenging: where and how big are the DERs; should all feeders or representative feeders be modeled?

Avoided distribution capacity, deferrals of upgrades, distribution impacts

DER may avoid the need for additional T&D capacity or defer the need for upgrades. DER may also incur costs.

- ► There are many impacts to consider: Equipment may not be capable of bi-directional power flow; DPV may lessen life of load-tap-changers; smart inverters can regulate voltage, etc.
- ► Options for calculating benefits:
  - Value DER contribution at peak hours at average distribution investment costs
  - Power flow modeling – load growth triggers upgrade that can be deferred by DER
- ► Options for calculating costs:
  - Assume zero – assume DERs limited to hosting capacity
  - Detailed interconnection study for a DER project would cost out a handful of workable mitigation options

Beware: Not easy to defer distribution capacity

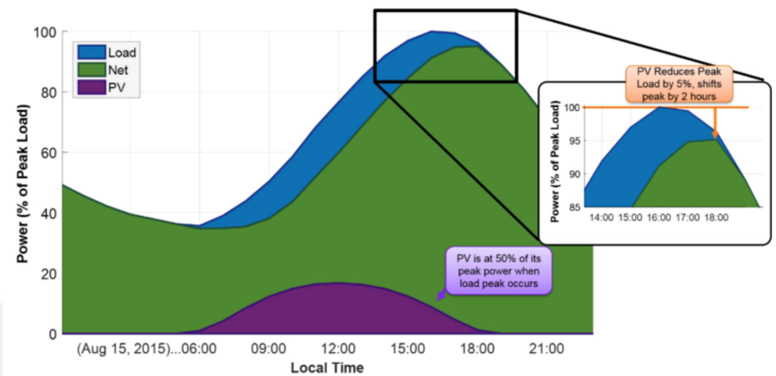
Avoided, deferred or incurred costs on distribution feeders/substation to accommodate load growth

- ► Is there a need for upgrades or new capacity?
  How much available capacity is there now and in the planning horizon?
- ► Does the output of the DER match the stressed hours/seasons of the capacity need?
- ► Is the DER location able to defer that capacity?
- ► Can the DER consistently/reliably provide power at that time? What happens if it's cloudy (for DPV)?

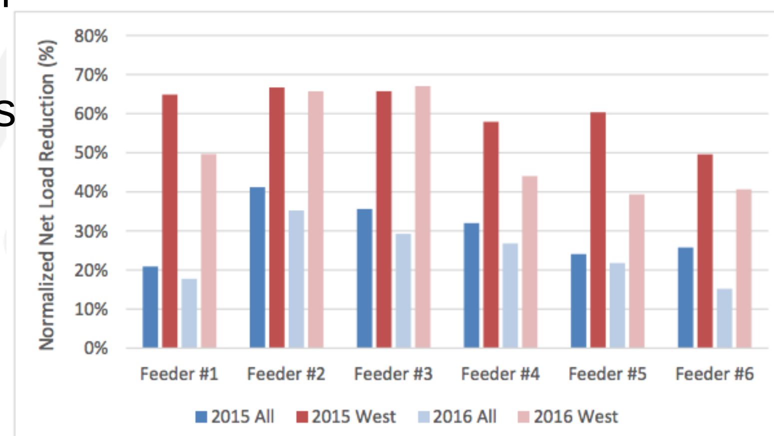
- ► Will the DER be available throughout the deferral period?
- ► Can the utility monitor/control the DER to meet distribution system needs?
- ► Calculation is feeder-dependent

Simulations and experience in distribution deferrals

- APS' Solar Partner Program results:
  - Adding PV did not reliably reduce peak load at house or secondary transformer, but did at the feeder level. ¼ of houses produced less than 5% at time of peak load.
  - Aggregated PV reduced peak net load by 15-41% of PV capacity
  - West-facing PV produced 2-3x the power at peak than the south-facing
  - Correlation between high feeder loading and high PV output



- Cohen, et al, analysis of PG&E feeder upgrades shows:
  - 90% of feeders receive no deferral benefit
  - Remaining feeders receive $10/kW-yr to over $60/kW-yr at very low penetrations
  - Benefits decline as PV increases: at 50% penetration, value is halved



https://www.epri.com/?_sm_byp=iVVwLTjLRHSkw6RL#/pages/product/000000003002011316/

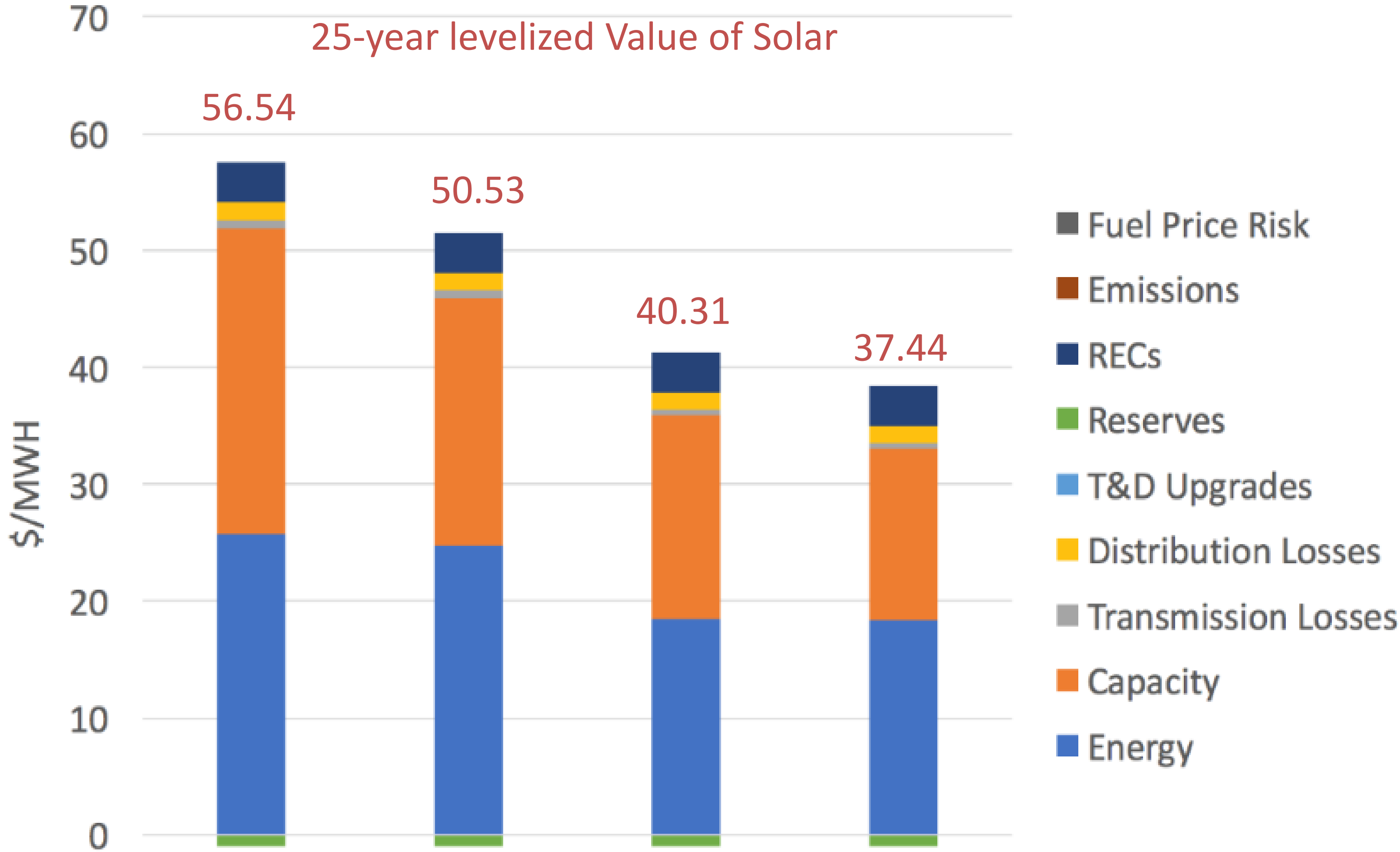
Cohen, et al, "Effects of distributed PV generation on California's distribution system, part 2: Economic analysis", Feb 2016.

Avoided emissions

DERs may avoid CO_2, NO_x, SO_2 and other emissions

- ► DERs may avoid emissions associated with avoided energy use. It may also avoid or incur emissions based on generator cycling (starts, ramps, part loading)
- ► Options for calculation in order of simplicity:
  - Assume marginal generator(s), emissions rate(s)
  - Correlation of historical LMPs to generator type and associated emissions rate
  - Production cost modeling simulates unit commitment and economic dispatch for each hour of the year. It can also capture cycling impacts.

Stacking the value stream for DPV



DPV	7.1MW	20MW	50MW	100MW
UPV	19MW	89MW	89MW	89MW

GE, *Solar Program Design Study*, 2017

Questions to ask utilities

- Scenarios
  - How did you select the scenarios? What factors will have the biggest impact on outcomes? How did you take stakeholder input into account?
  - Where did the input data for load, energy efficiency, demand response, DPV, storage, and other DERs come from and are those reliable, recent studies?
- Hosting capacity
  - How do you plan to use these results?
  - What method was used and is that method appropriate for the application?
  - Which power system criteria did you evaluate?
  - At what level of granularity did you analyze the criteria?
  - Do you allow voltage control devices to adjust during iterations or are they fixed?
- LNBA
  - What methods were used to quantify each component? Do you think results are optimistic? Conservative?

Resources

- California DRPs http://www.cpuc.ca.gov/General.aspx?id=5071
- Multiple Scenario Planning Assumptions http://drpwg.org/wp-content/uploads/2017/04/R-14-08-013-Revised-Distributed-Energy-Resource-Assumptions-Framework-....pdf
- New York REV DSIPs http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=14-m-0101&submit=Search+by+Case+Number
- NREL on DPV benefits and costs https://www.nrel.gov/docs/fy14osti/62447.pdf
- DSTAR on hosting capacity http://www.dstar.org/research/project/103/P15-6-impact-and-practical-limits-of-pv-penetration-on-distribution-feeders
- EPRI on hosting capacity https://www.epri.com/#/pages/product/1026640/
- EPRI on shorthand equations https://www.epri.com/#/pages/product/3002006594/

Any Questions?

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Load growth (including EVs & other new loads)

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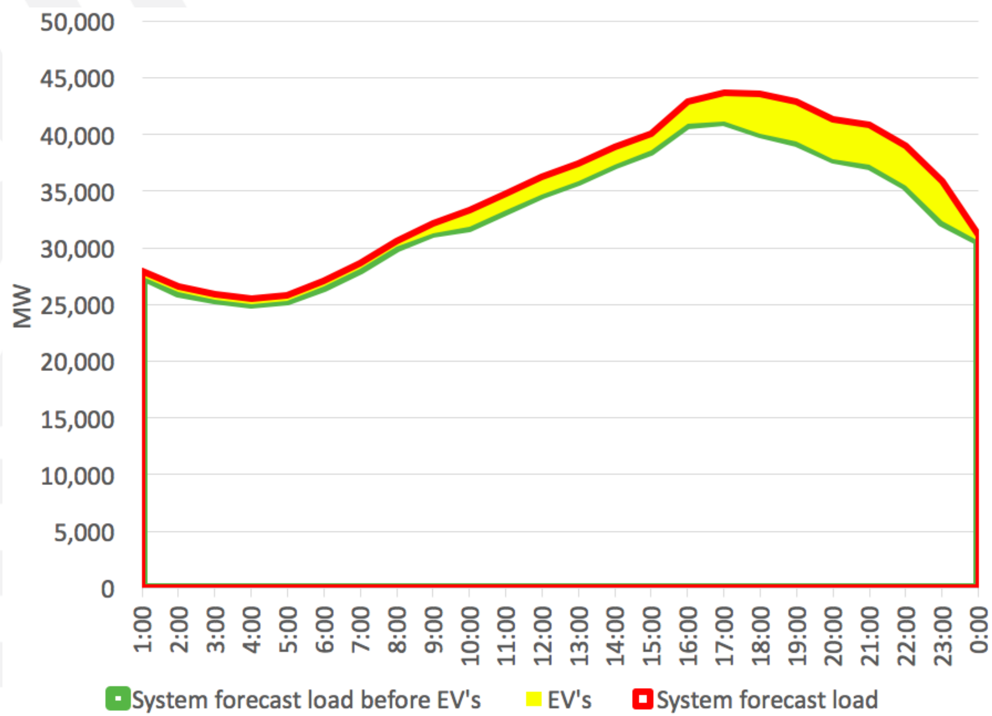
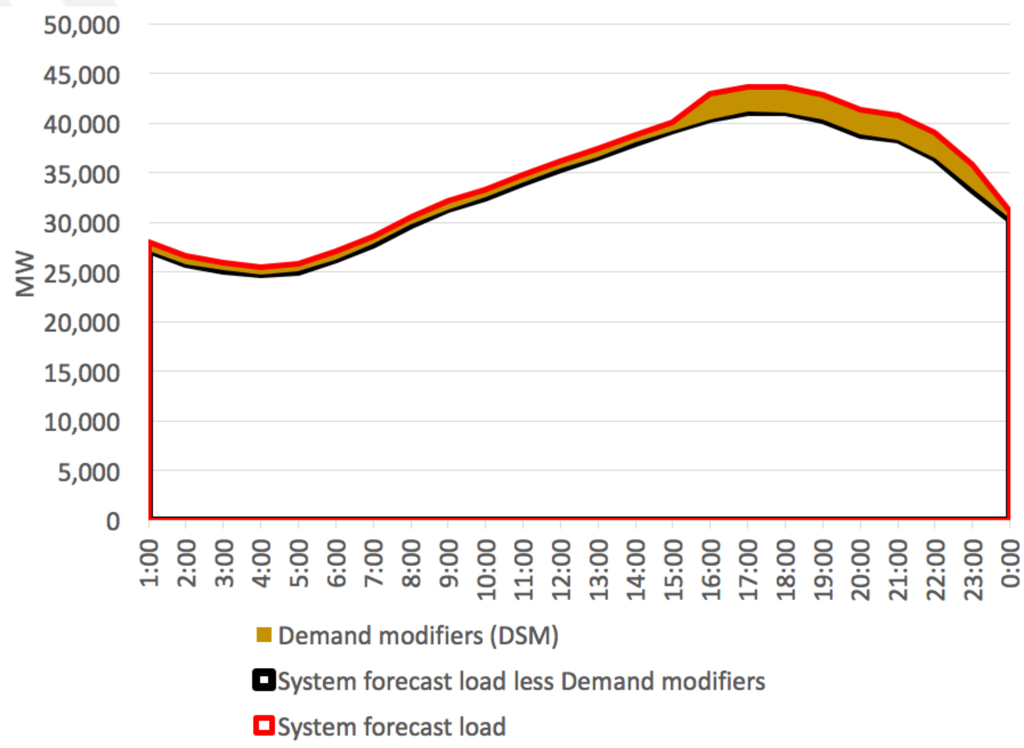
- ► Determine system load growth
  - Consider rates of growth for each customer class
- ► Add impact of EVs (and other new loads)
  - EV charging patterns



Demand modifiers

- ► Energy efficiency
- ► Demand management: Peak shaving
- ► Demand response
- ► Rate structure

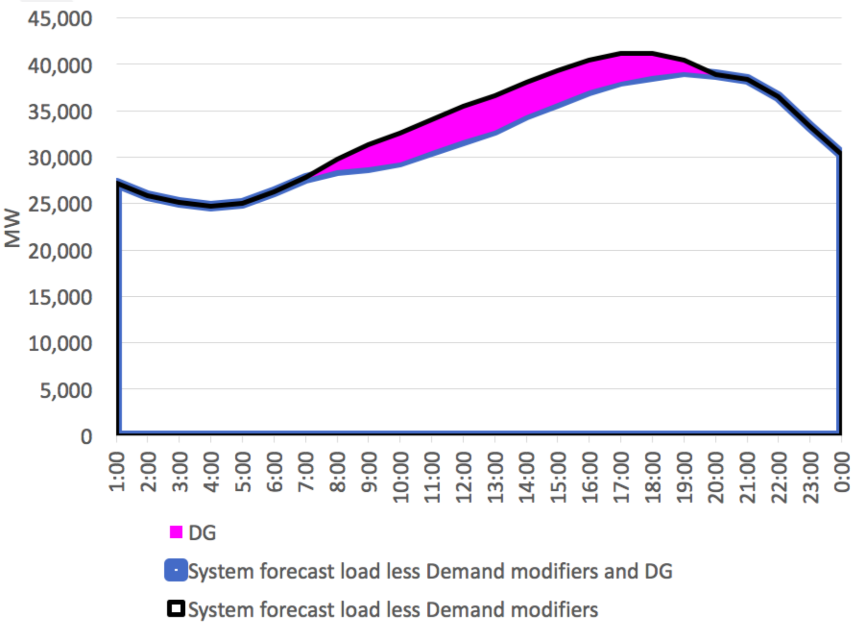
- ► How is DR dispatched? How much does energy efficiency contribute at peak?



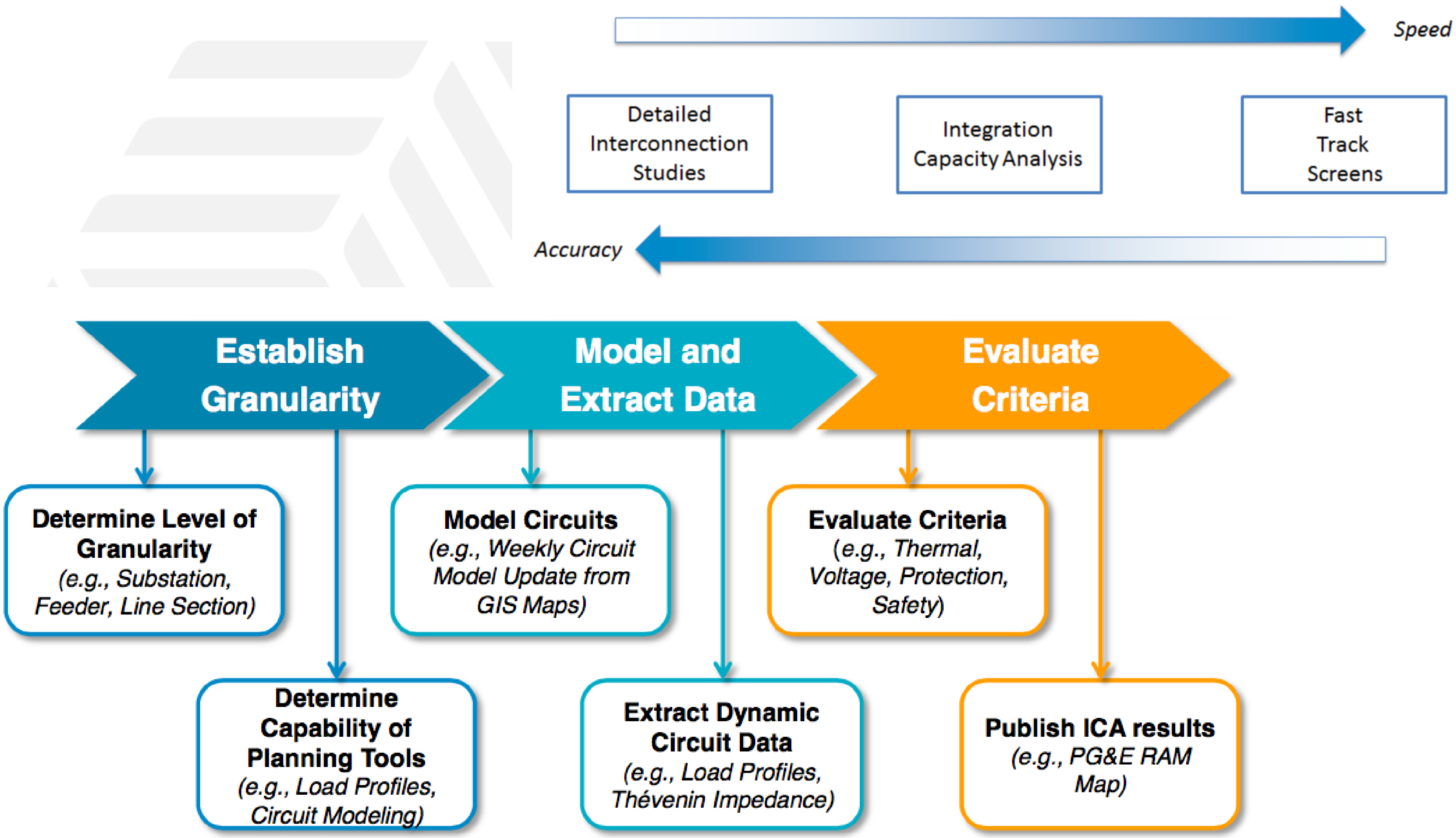
Time-varying rates can be a significant demand modifier

Impact of DG on load

- ► DG includes DPV, storage, fuel cells, etc.
- ► System Forecast Load less Demand modifiers and DG
  - This is how much utility-scale generation is needed at any time

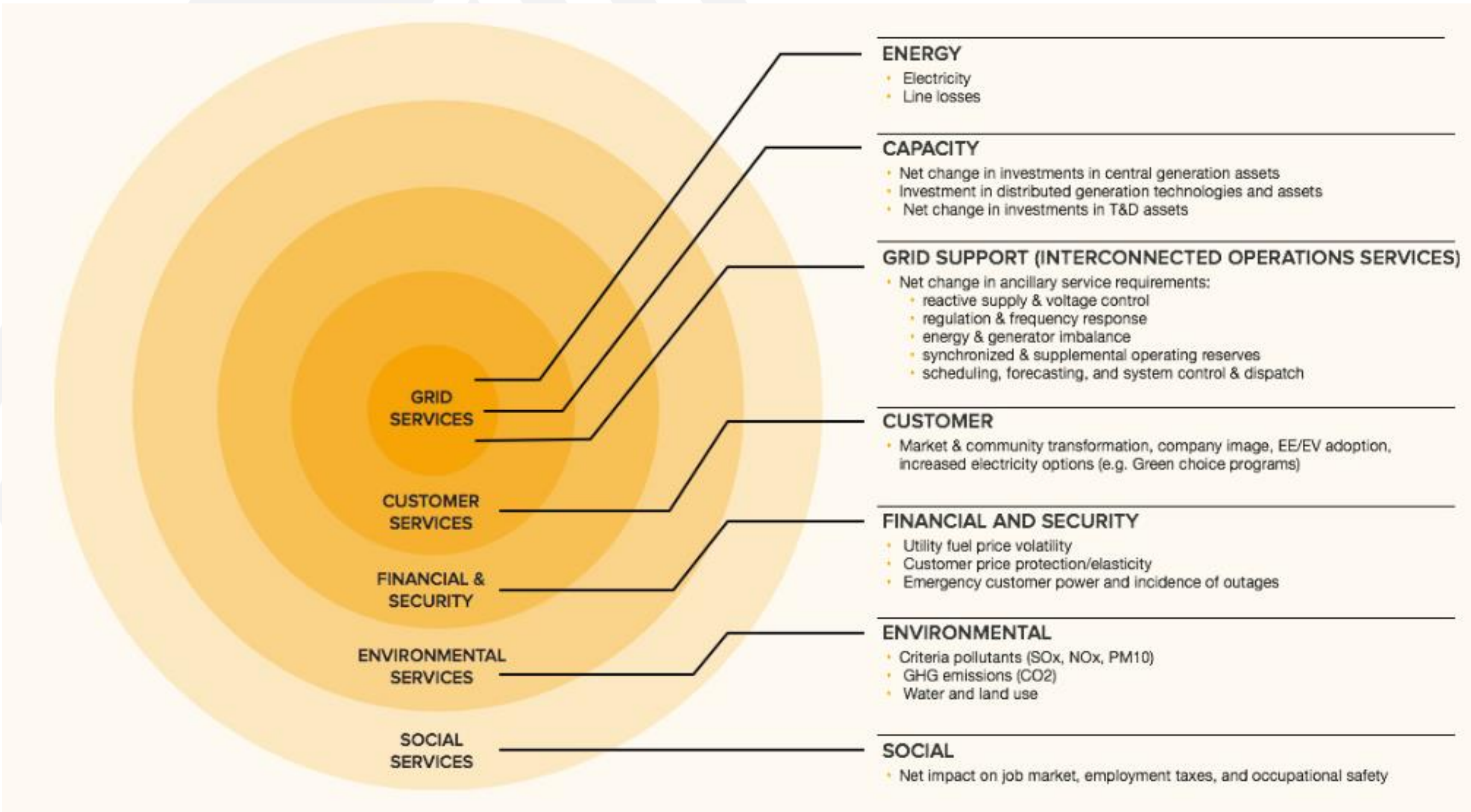


Streamline Interconnection Processes



Source: PG&E DRP Webinar, 2015

Benefits of DERs



eLab, RMI, *Rate Design for the Distribution Edge*, 2014